# CDF

# Physics Analysis / Publication Overview

## - experiment, computing, and physics status -

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Entry to CDF Physics
http://www-cdf.fnal.gov/physics/physics.html

# The CDF Collaboration

## North America

3 Natl. Labs
27 Universities

3 Universities

## Europe

1 Research Lab
6 Universities

1 University

4 Universities

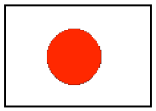
2 Research Labs

2 Universities

1 University

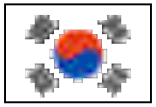
1 University
1 lab

## Asia



4 Universities
1 Research Lab

1 Research Lab

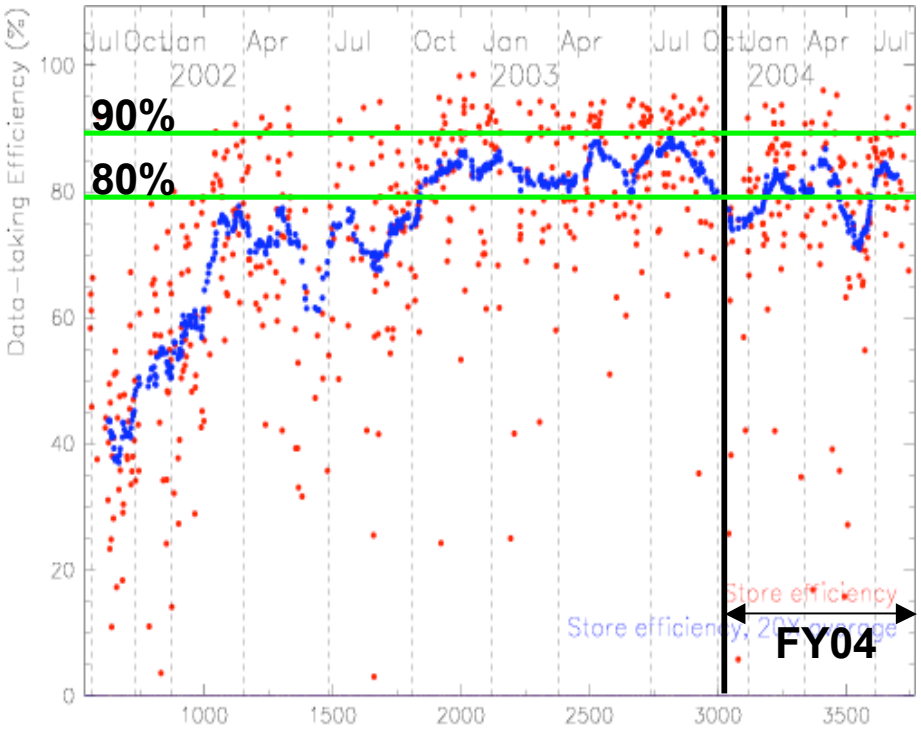


3 Universities

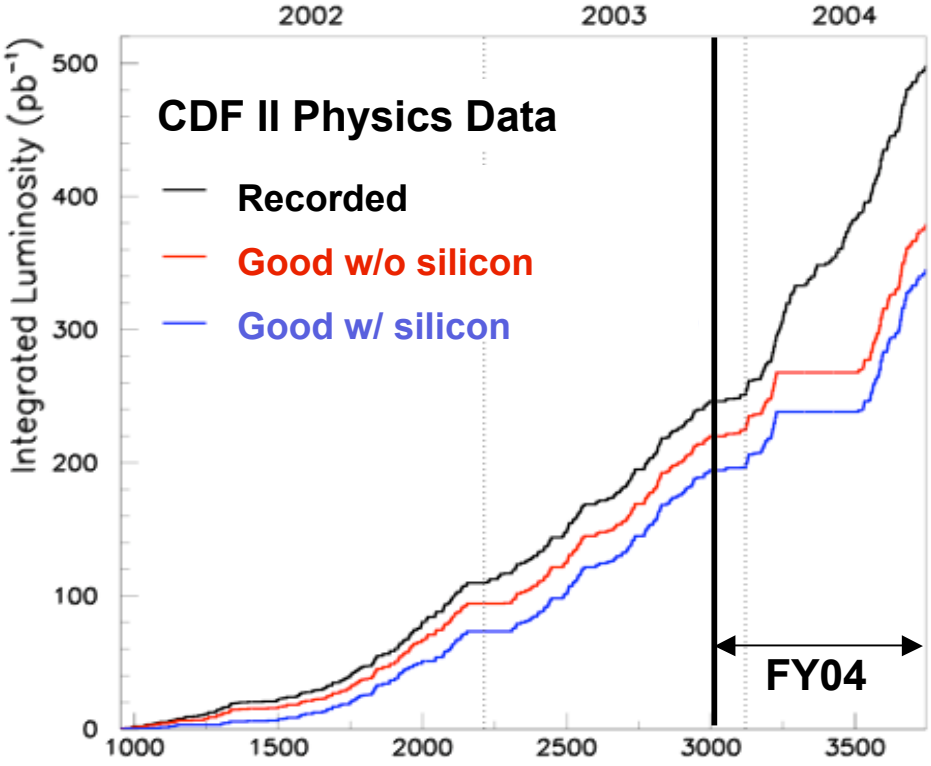
12 countries, 61 institutions, ~800 physicists

# CDF Data Taking Efficiencies

Data Taking Efficiency
L(recorded) / L(delivered):
beam losses, Triggers/DAQ,
COT related, other systems




**Data for Physics 340 - 390 pb$^{-1}$**
excluding "compromised
COT performance period"




**Run II Goal > 90%**

# Issues Faced by CDF Operations in FY04

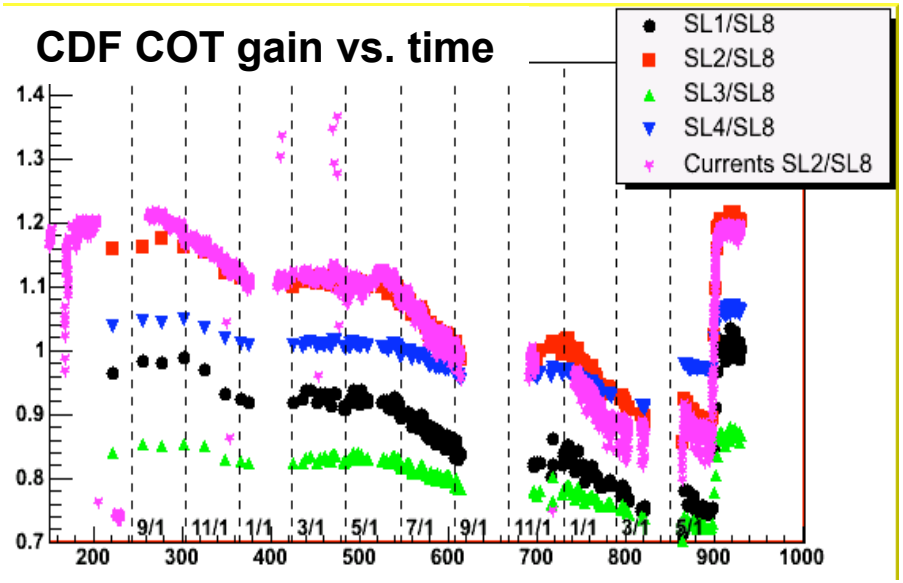
- Accelerator incidents damaging the Silicon detector
  - Lost ~2% chips
- Losses from accelerator: both “DC” beam as well as in abort gaps
  - Silicon placed on Standby
    for high loss conditions and high loss potential
  - Conditions much improved at the end of FY04
- Loss spikes resulting from truck traffic and changes in HVAC conditions in the collision hall

- CDF vs. D0 luminosity differences at the start of stores
  - A lot work by both experiments and Accelerator Division

- Substantial loss in gain for the Central Outer Tracker

# Gain Loss of the CDF Outer Tracker (COT)

- COT experienced significant gain loss - up to x2 loss in gain that is both *r,* $\phi$ and *z* dependent.
- Turned off SL1,2 and reduced HV of SL 3,4,5 while we investigated the problem to prevent further damage - in case the process was irreversible. (Compromised COT performance Period) - B physics program suffered during this period due to trigger track fakes
- Formed an international committee of chamber experts to advice CDF, chaired by R. Kephart.
- Degradation source comes from hydrocarbons coating “sense” wires.




- **Oxygen** fixed it.
- Used the recirculation system (built to increase gas flow rate by x10) to add air, then Oxygen.
- Chamber is now fully recovered (late May, 2004).
- 85 $pb^{-1}$ of date collected with compromised chamber.

# Issues Facing CDF Operations in FY05

- Forward Calorimeter Energy Scale is not stable.
  - Radiation damage causing degradation of plastic in plug region
  - Need to monitor the detector, and calibrate it more automatically.

- Monitoring of Low Beta Quad Positions - an issue for beam stability (we are sensitive to their positions - losses).

- Remain vigilant for further signs of gain loss in the COT.
  Goal is to reproduce effect in a test chamber.

- We need to extend the lifetime of the Silicon detectors by a factor of 2 beyond design.
  - Even more crucial with the renewed optimism based on this year's accelerator performance
    - $\geq 4$ fb$^{-1}$ by 2008 - baseline
    - ~8 fb$^{-1}$ (x2 improvement) if electron cooling works maximally - design
- The unknown problems

# Triggers and DAQ

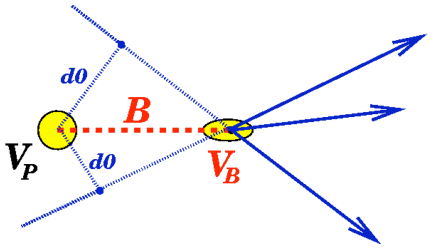
CDF: High rate trigger system for B Physics - Challenging

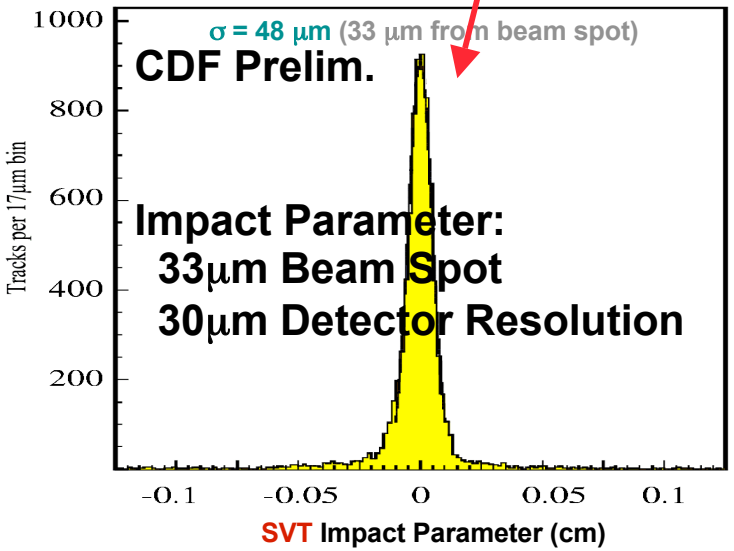
| Level | Input / Output | Rejection Rate | # Paths | Information |
|---|---|---|---|---|
| 1 | 1.7MHz / 25kHz | ~70 | 40 | Tracks, EM/Had Cal, Muon |
| 2 | 25kHz / 350Hz | ~70 | 120 | Shower Max, SVT Algorithms run in Processor |
| 3 | 350Hz / 70Hz(20MB/s) | ~5 | 300 | Full Detector Readout Offline Reconstruction |

**Trigger Paths:**

- e, μ, τ, γ, track, jet, B, ν, …
- Combinations of these objects

**Silicon Vertex Trigger (SVT)**



# Trigger Issues Facing CDF Operations in FY05

- Coping with 25% more Initial Instantaneous luminosity by the end of FY05
  - Background rates grow faster than the signal rates.
  - To remain efficient for physics, it is not sufficient to maintain status quo.
  - Must continue to improve trigger intelligence (a lot of improvement has been made) and throughput to keep up with higher luminosity.

- Some of Trigger/DAQ "Run IIb" upgrades already installed. Will be commissioned with beam.
  - New Level-2 (Pulsar System) Decision Crate
  - Parallel Data Logger - writing simultaneously to multiple disks (20MB/s → 40MB/s)

# Offline Computing Status and Plan

- Globally distributed computing resources
  - Data Logging bandwidth upgrade
    - 20MB/s → 40MB/s(FY05) → 60MB/s (FY06)

      to retain B physics program at high luminosity
  - Need more computing resources for analysis and MC production
  - Proposed **remote** computing resources to IFC (International Finance Committee) in 2003, then to PAC in 2003.
  - 2003 PAC endorsed our proposal.
  - Significant expansion of remote computing capacity since 2003.
    - Goal and achievement of CPU located off-site.

| Time | Goal (offsite computing) | Achieved |
|---|---|---|
| Summer 04 | 25% | 35% |
| Fall 04 | | 43% |
| Summer 05 | 50% | |

# Offline Computing Status and Plan (cont.)

- Globally distributed computing resources (cont.)
  - Contribution from off-site computing
    - Currently Monte Carlo Production
    - Moving toward significant user analysis
      - Locate datasets at remote institutions - Italian institutions, Karlsruhe
      - Physics analyses produced with these datasets.
        - » B physics: J/$\psi$ lifetime, B tagging
        - » Top physics: Single top search
  - Computing Resources Board
    - Oversees usage of remote resources
    - Coordinates policy, deployments, problem solving
- CDF working towards common GRID tools with Computing Division.

# Data Reprocessing

- CDF Production executable is fast.
  - As luminosity increases, the executable time grows ~linearly with a small slope: ~40% increase from $10^{31}$ $cm^{-2}s^{-1}$ to $10^{32}$ $cm^{-2}s^{-1}$.
- Runs on small farms.
- Reprocessing data.
  - Over 1 Billion events with ~500 $pb^{-1}$
  - Early data (Mar. 02 - Aug. 03) - reprocessed twice.
  - This year's data - reprocessed once.
  - ~10 million events / day
  - Took ~2 months to reprocess all the data up to Feb. 2003 - big effort to prepare ICHEP04.
- High quality (well calibrated) data - likely we will not reprocess this data again.
- No problem processing data expected this year in real time

# Data Processing, Software (FY05) Plan

- Single-Pass Processing
  - Procedure up to now:
    - Real time (within 3 days) calibrations - COT, SVX, Beamline
    - Process full data
    - Calorimeter calibration (a couple of months)
    - Reprocess full data
  - Move toward Single-pass processing (begins with this winter's data).
    - Process ~20% of full data for monitoring and calibration
      - Real time (within 3 days) calibrations - COT, SVX, Beamline
      - Calorimeter calibration within a month
    - Process full data
- Expand offsite computing usage for MC prod:~300 M events (x2 FY04)
- Code releases
  - So far every 6 months. Codes are maturing - once a year
- Organized effort to streamline offline operations: data and MC processing, to reduce person power needs in pre-LHC era
  - Single-pass Processing, SAM and GRID tools, …

# Resource Issues Facing Beyond 2005

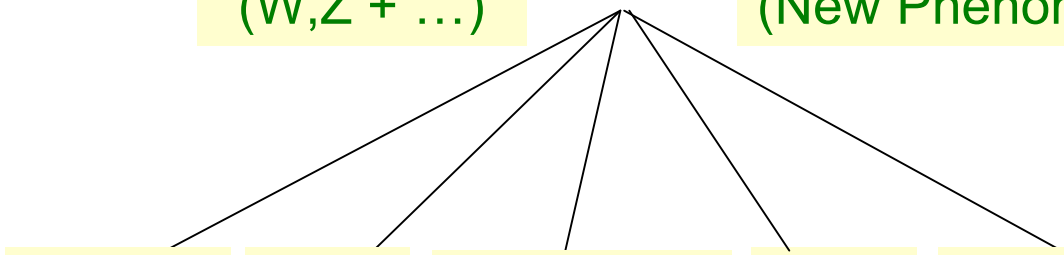
- Renegotiating MOUs with institutions, current & beyond 2005.
  - Current MOUs are good through 2005, but written in ~2001
- Many groups being “downsized”
  - By pressure from funding agencies
  - Need to ramp up on LHC
- Will get very difficult to operate the experiment and do physics.

- Institutions have been hiring CDF/LHC postdocs - do service work on LHC and physics/operations(?) on CDF.
  - Postdocs need physics analysis for career advancement.
- LPC (LHC Physics Center) - promise to mitigate sudden flow
  - Postdocs can find critical mass of people at Fermilab preparing for LHC.
  - Maintain a role in both CDF and LHC.

# Physics Group Organization

Physics Groups:
2 leaders / group

QCD | B | Electroweak (W,Z + …) | Top | Exotic (New Phenomena)



Analysis Groups:
2 leaders / group

dilepton | l+jets | all hadrons | mass | single top

Common Tools,
Issues:

Working groups:
Tracking, e, μ, τ, γ, b-tagging, jet calibration, …

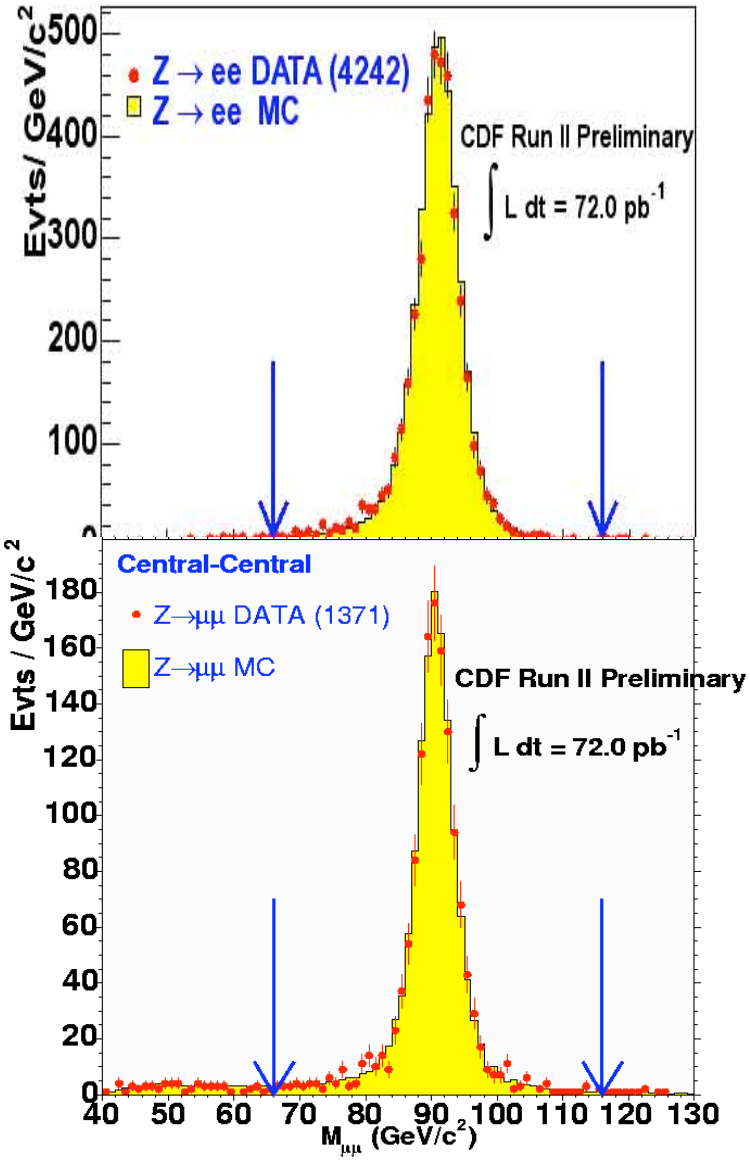
Final results discussed at Joint Physics Meeting

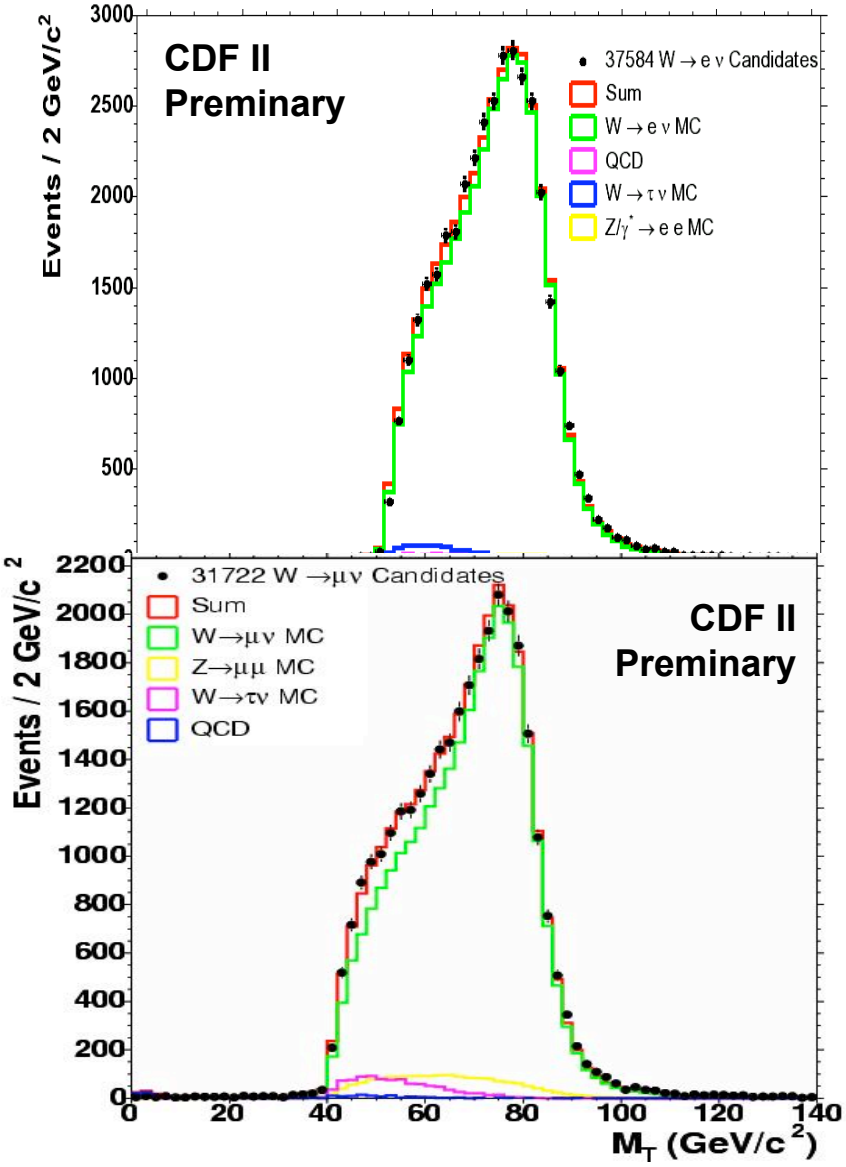
In addition

Detector Calibration
Offline Reconstruction
Monte Carlo Generation, Simulation, Production

# Detector and Trigger Performance, Common Analysis Tools

# COT Tracking, Calorimeter and Simulation



# Silicon Tracking

**Silicon System:**

L00 (1 layer, single sided)
SVX II (5 layers, double sided)
ISL (1 layer in $|\eta|<1$, 2 layers in $1<|\eta|<2$), double sided)

**SVX II:**

94% efficiency with *r-φ*
83% efficiency with *r-φ* and *z*
0.5-1.5% fake rate

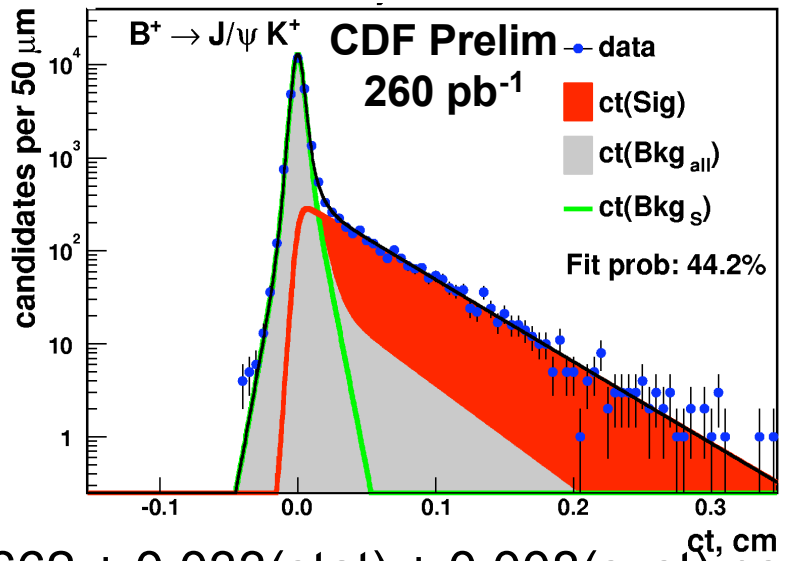
**Added ISL:**

Used in forward-backward W charge asym. & Z' search

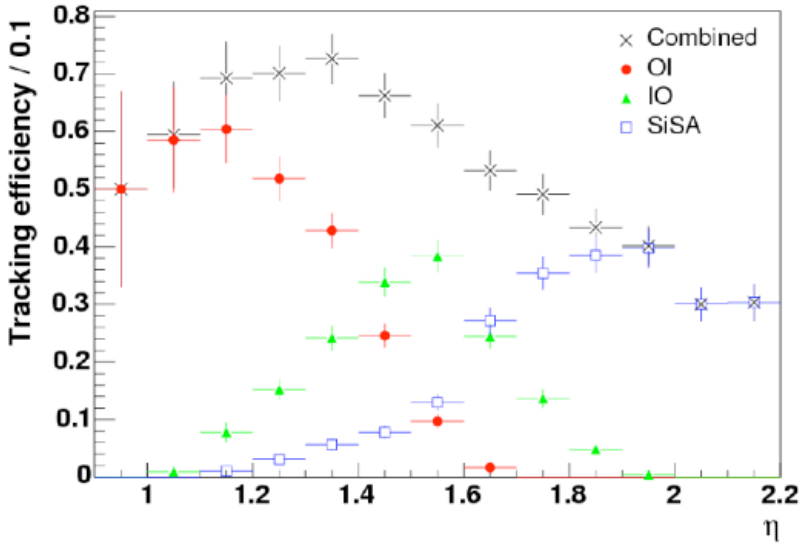
**Added L00:**

implemented in tracking
began using in physics analysis

**Performance keeps improving.**



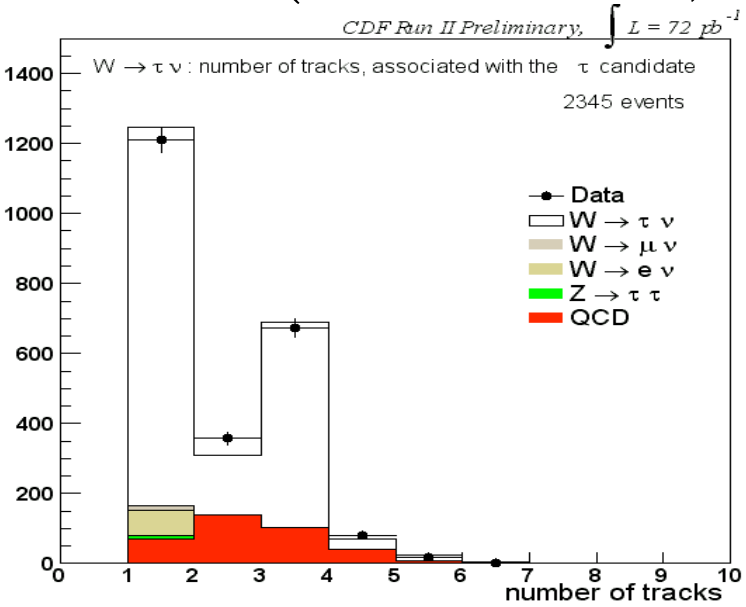

$\tau(B^{\pm}) = 1.662 \pm 0.033(\text{stat}) \pm 0.008(\text{syst})$ ps



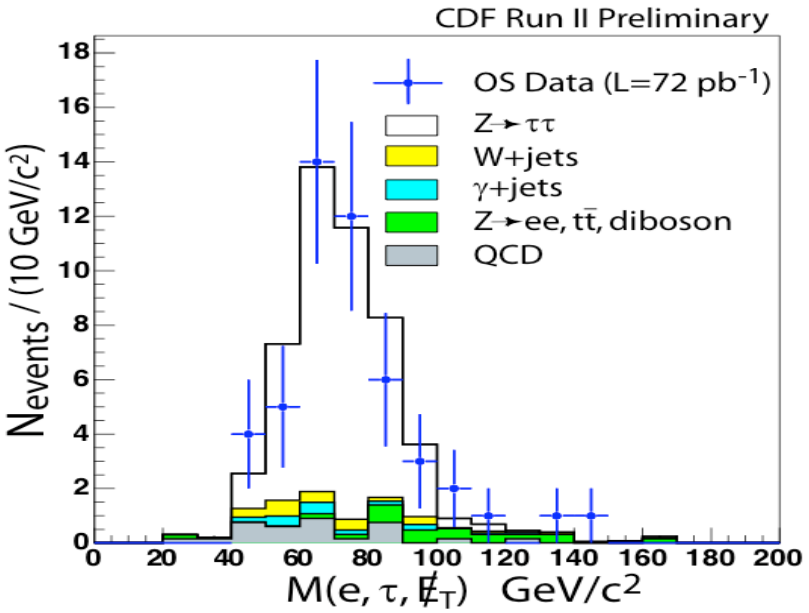
# Tau and Hadron Identification

- Tau - Important for Physics beyond the Standard Model:
  - many models with enhanced $\tau$ couplings

$W \rightarrow \tau\nu$ ($\tau \rightarrow$ hadrons + $\nu$)




$Z \rightarrow \tau\tau$ ($\tau \rightarrow e\nu\nu$, $\tau \rightarrow$ hadrons)




- dE/dx from Drift Chamber and Time-of-Flight Detector
  - B physics: K-$\pi$ separation at low $P_T$
  - New particle searches: charged massive particles

# Run II Publications

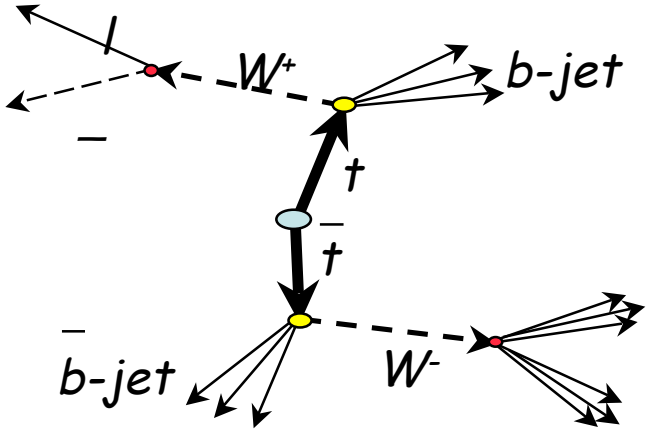
- 59 papers - published, submitted, or under Collaboration review
  - 17 papers published or submitted
    - 6 papers published - 5 PRL and 1 PRD
    - 2 paper accepted - 2 PRL
    - 9 papers submitted - 5 PRL and 3 PRD, 1 PRD-RC
  - 5 second drafts out to the CDF collaboration
  - 7 first drafts out to the CDF collaboration
  - 30 under Godparents review
- 7 godparent committees about to be assigned.
- Time scales for publication vary due to different degrees of sophistication required by each particular analysis.

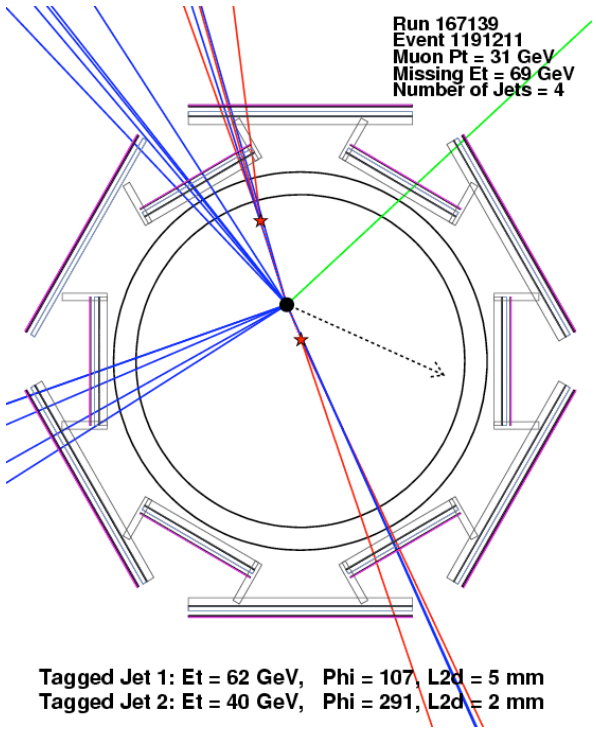
| year | 2001<br>First Collision<br>Commissioning | 2002<br>First Physics<br>data | 2003 | 2004 | 2005<br>Goal |
|---|---|---|---|---|---|
| # of papers | | | 4 | ~18 | ~40 |

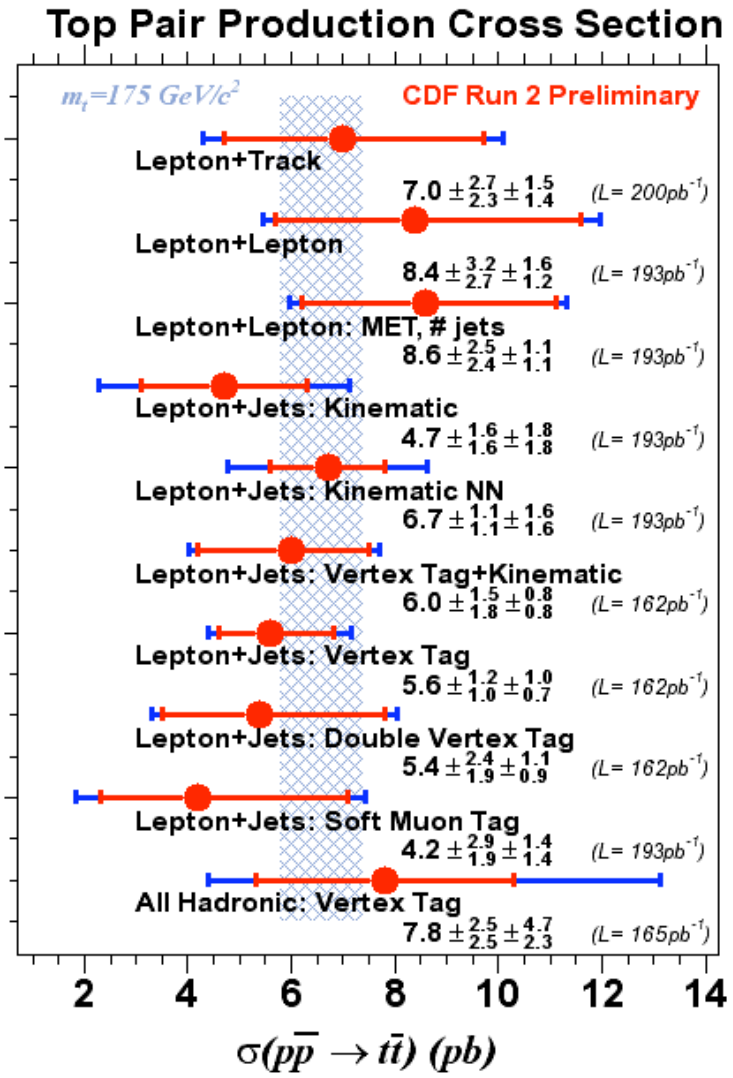
# Physics with Top Quarks

- Publications:
  - 4 papers published or submitted
    - Top pair cross section in dilepton (PRL 93, 142001, 2004)
    - Top pair cross section in lepton+jets with vertex b-tag & kinematics (submitted to PRD)
    - Top pair cross section in lepton+jets with vertex b-tag (sub. PRD)
    - Single top search (submitted to PRL)
  - 9 papers Collaboration publication review
    - Anomalous kinematic distribution in top dilepton
    - Top pair production in lepton+jets with kinematics
    - Top pair production in lepton+jets with soft-muon tag
    - Top pair production in e/$\mu$ + tau
    - Top branching ratios
    - W helicity
    - Top mass in lepton+jets with dynamical likelihood method
    - Top mass in lepton+jets with template method
    - Top mass in lepton+jets with multivariate method

# Top Pair Production - Cross Section

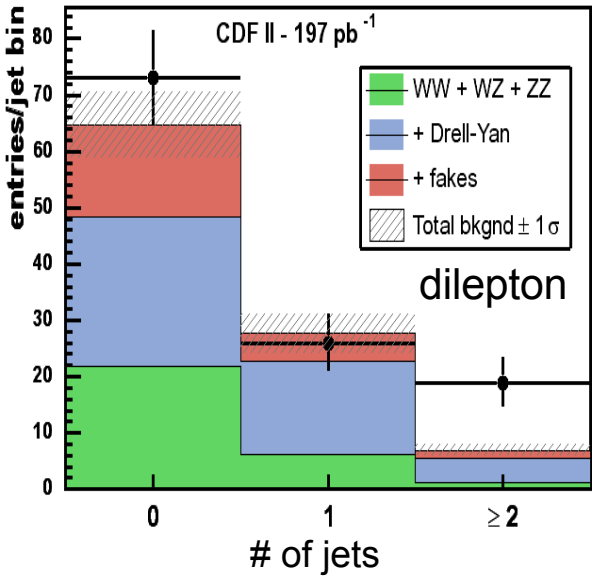


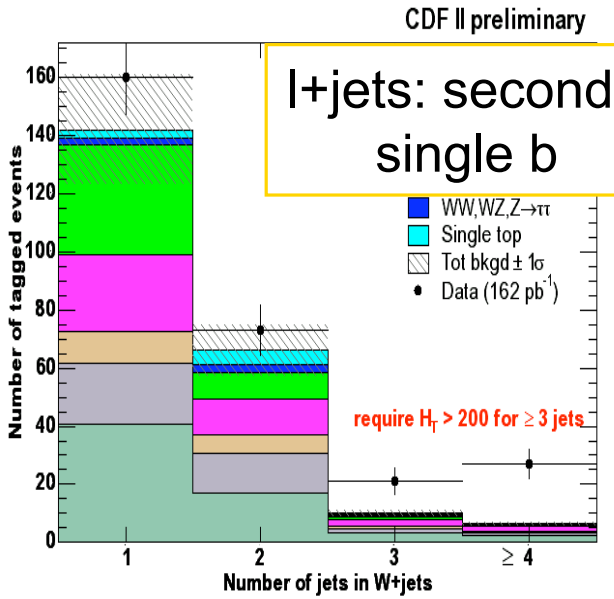



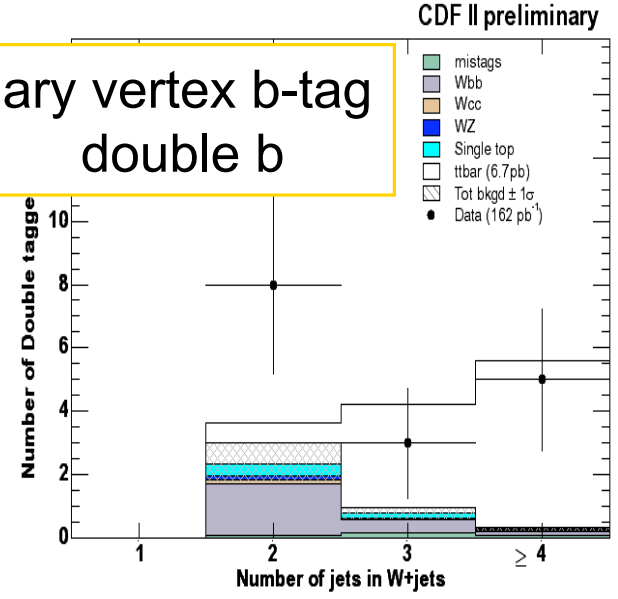



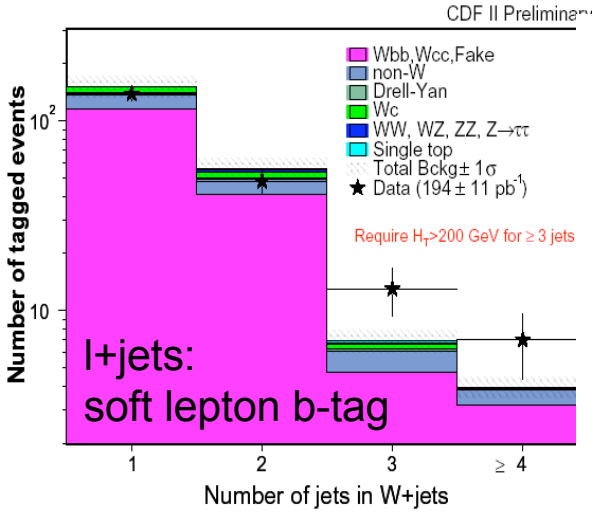
# Top Pair Production - Cross Section

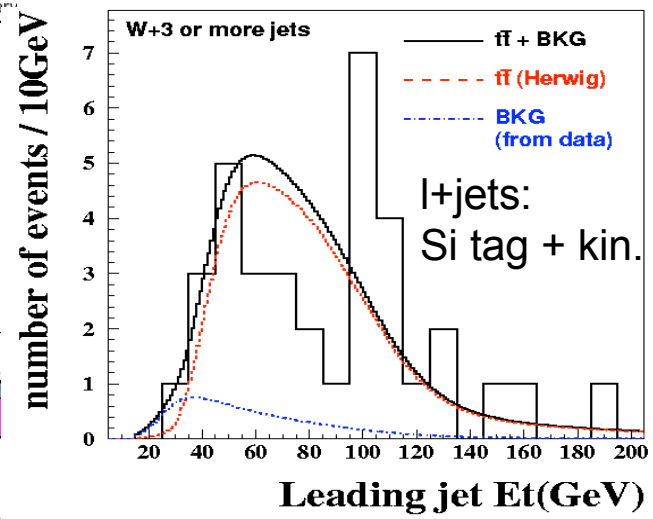
Different measurements: Test different assumptions, Look for new physics

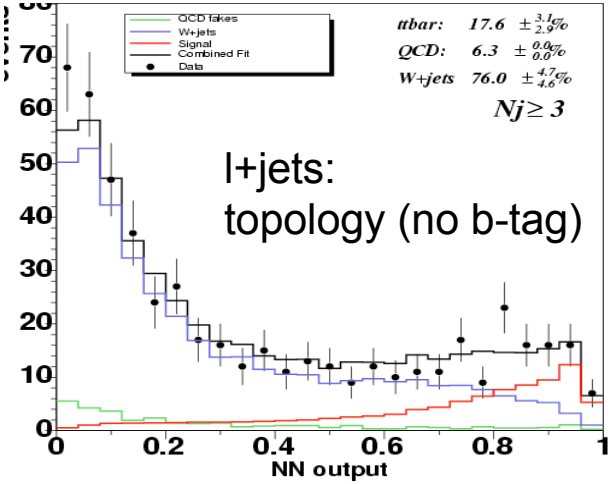


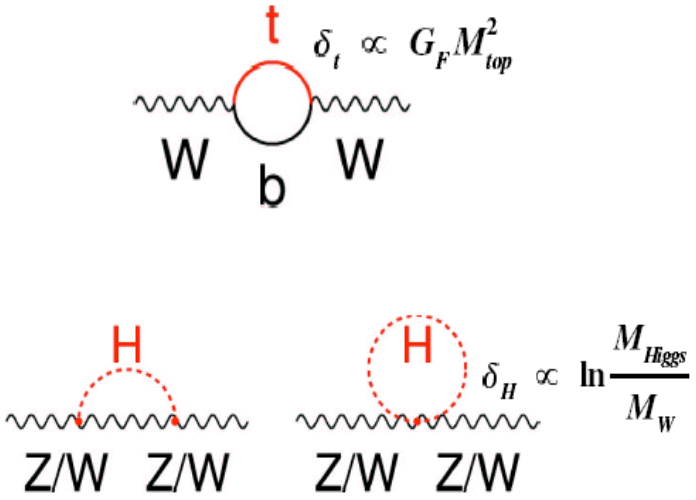



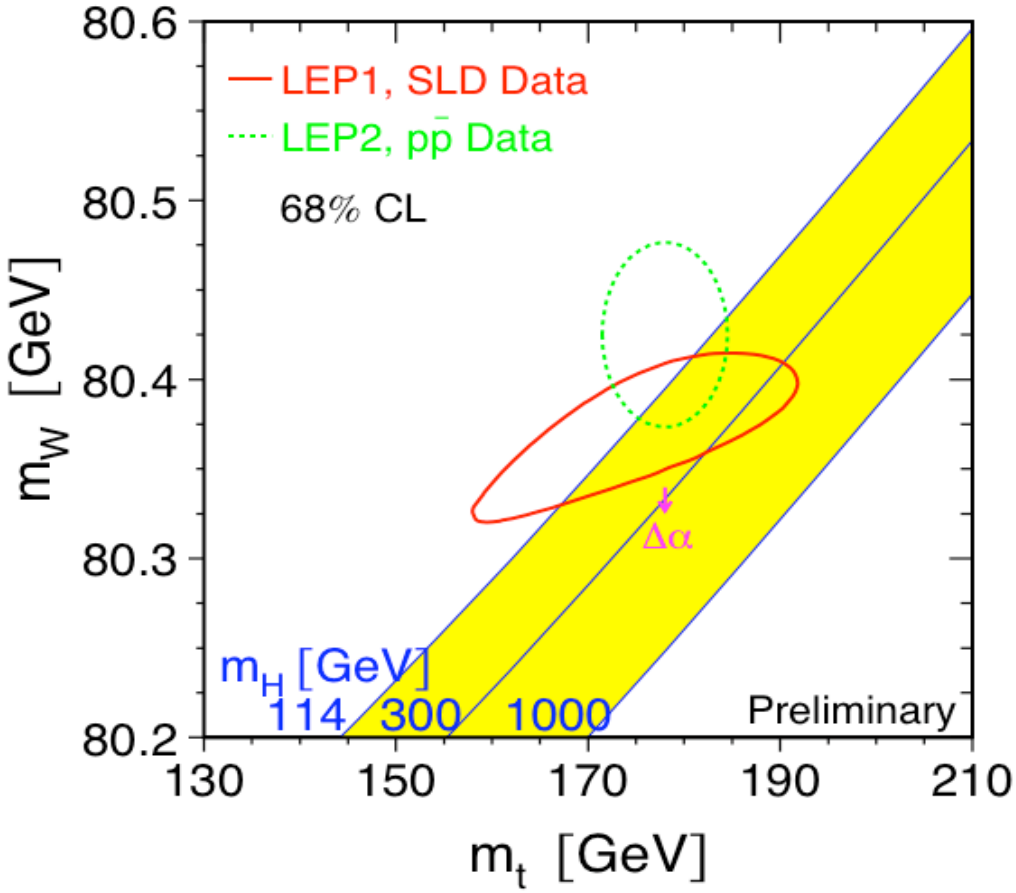



# Measurements of $M_{top}$ and $M_W$

- Important SM parameters
- Ingredients of indirect Higgs mass constraint

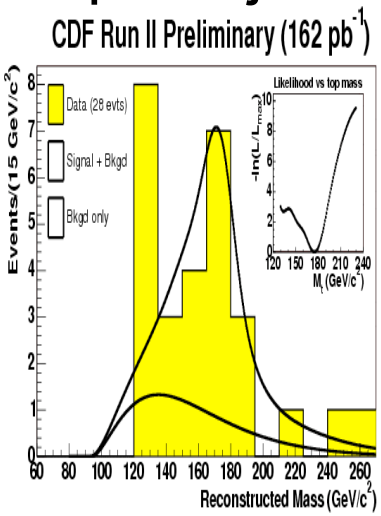


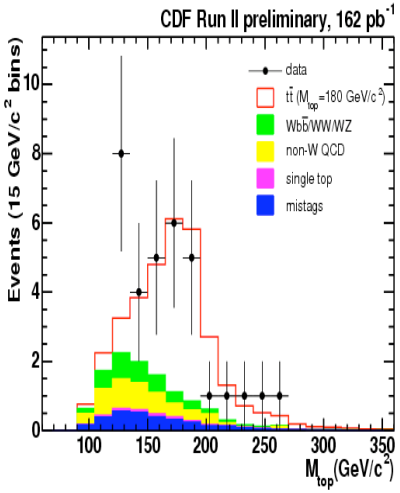



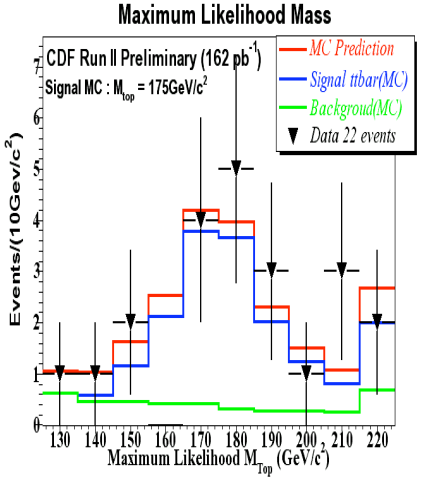

- Top mass measurement
  - Complicated event topology

# Top Quark Mass Measurements

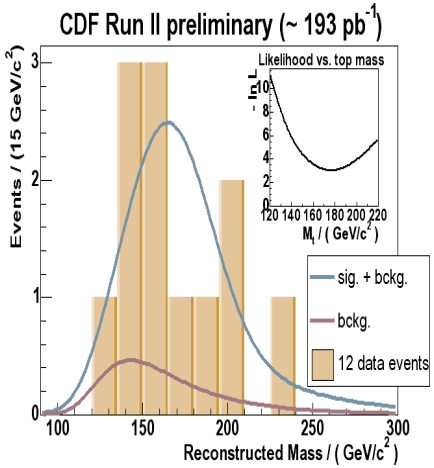
## Lepton+jets:

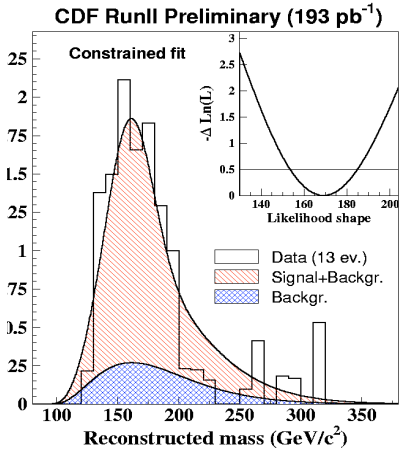


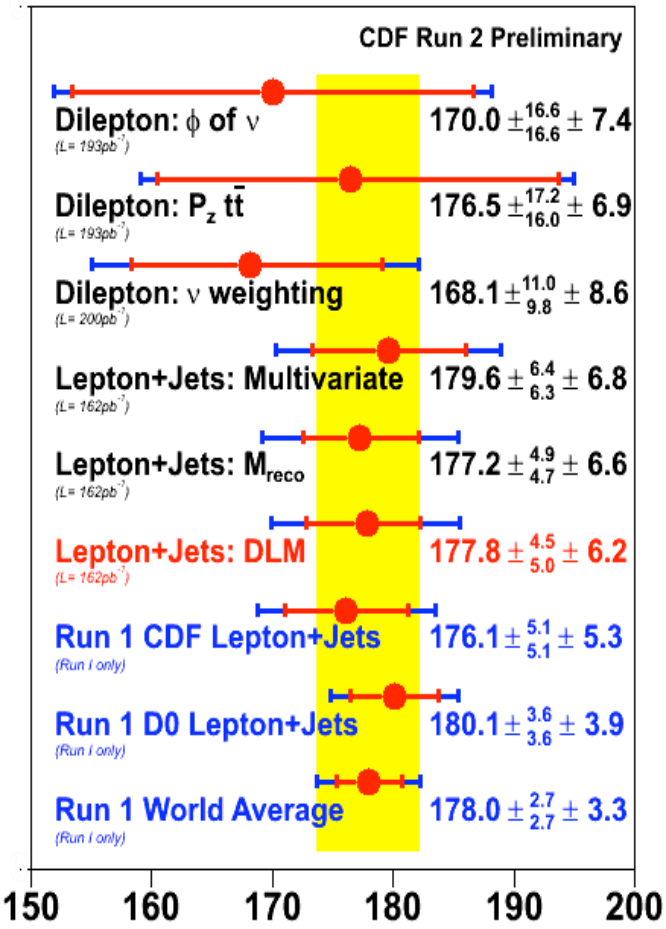




## Dilepton:



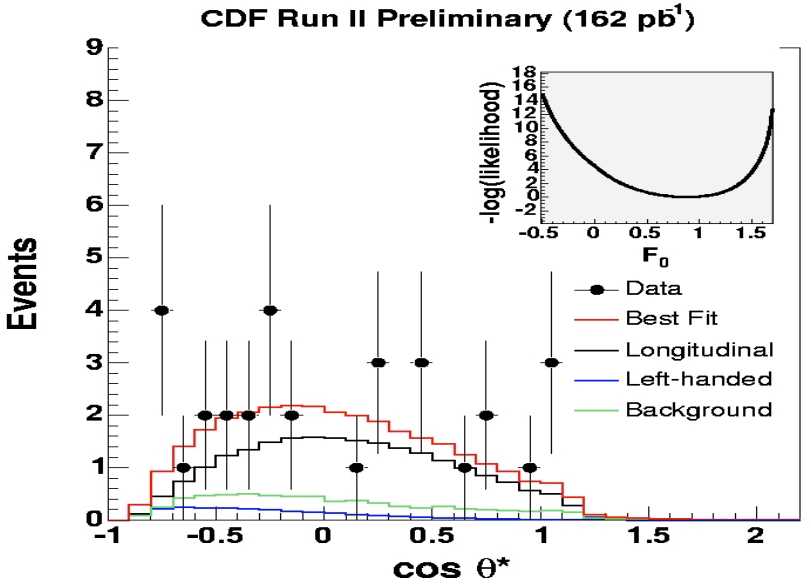

## 162pb$^{-1}$ (l+jets), 193pb$^{-1}$ (ll)

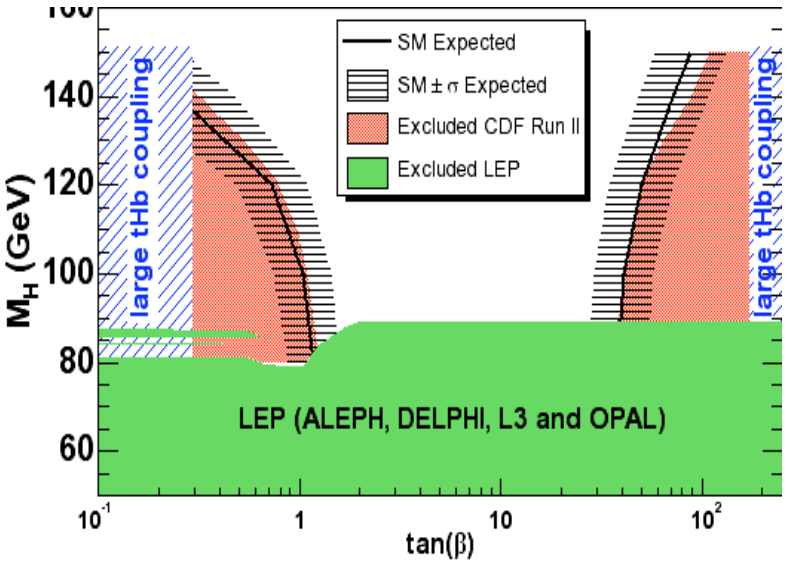



2 PRDs under Collaboration review. Improved simulation: ~6 GeV → ~3 GeV

# Top Quark Properties

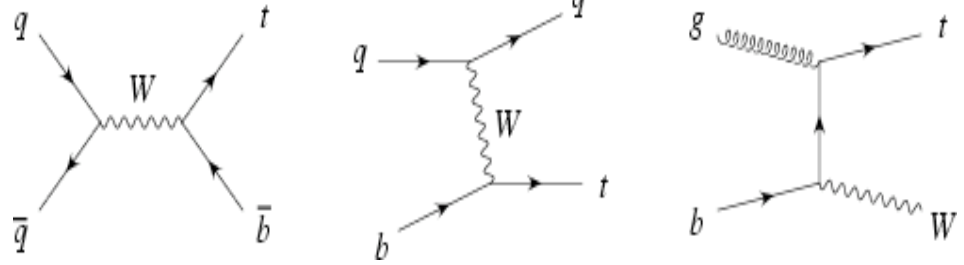
- Is *tWb* vertex SM? - W helicity
  - SM is V-A theory:
    - $F_0$ = 70% longitudinal
    - $F_-$ = 30% left-handed
  - Assume $F_+$=0 (ie no V+A)
    - Measure $F_0$
    - $F_0 > 0.25$ @ 95% C.L.
- Unexpected top decay modes?
  - 3 gen. CKM matrix unitarity
    - $|V_{tb}| \sim 1.0$
    - BR(t→Wb)/BR(t→Wq) ~1.0
    - BR(t→Wb)/BR(t→Wq) > 0.62 at 95% C.L. (CDF)
- t → $H^+$b instead of $W^+$b ?



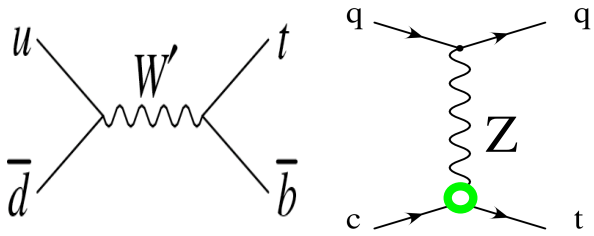
# Single Top Production (via weak interaction)

– Probe $|V_{tb}|$ directly



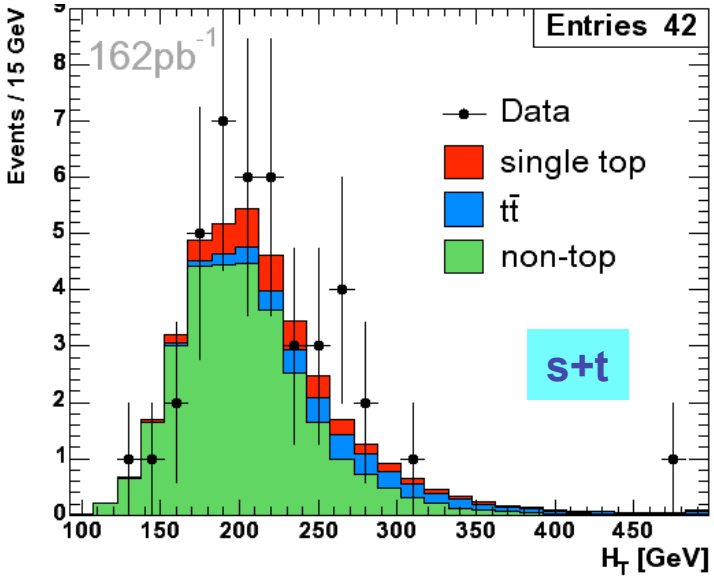

0.88 ± 0.11 pb  1.98 ± 0.25 pb  < 0.1 pb

New Physics!




– Similar topology to Higgs Signature (WH → Wbb)

– Topology: somewhere between W+jets and Top pair




95% C.L. limits Observed (Expected)

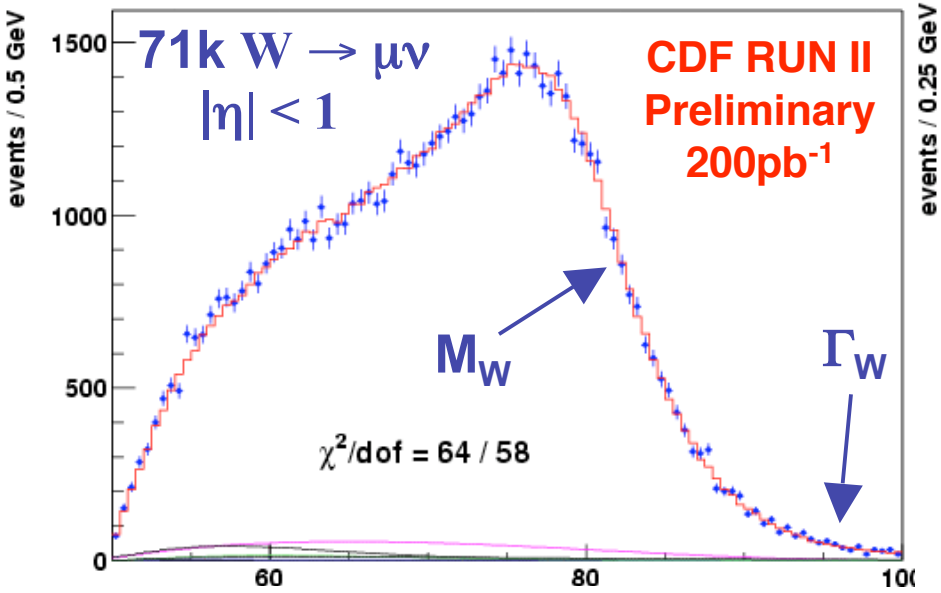
**CDF Prelim. 162 pb$^{-1}$**

| Channel | CDF (pb) |
|---|---|
| **s** | < 13.6 (12.1) |
| **t** | < 10.1 (11.2) |
| **s+t** | < 17.8 (13.6) |

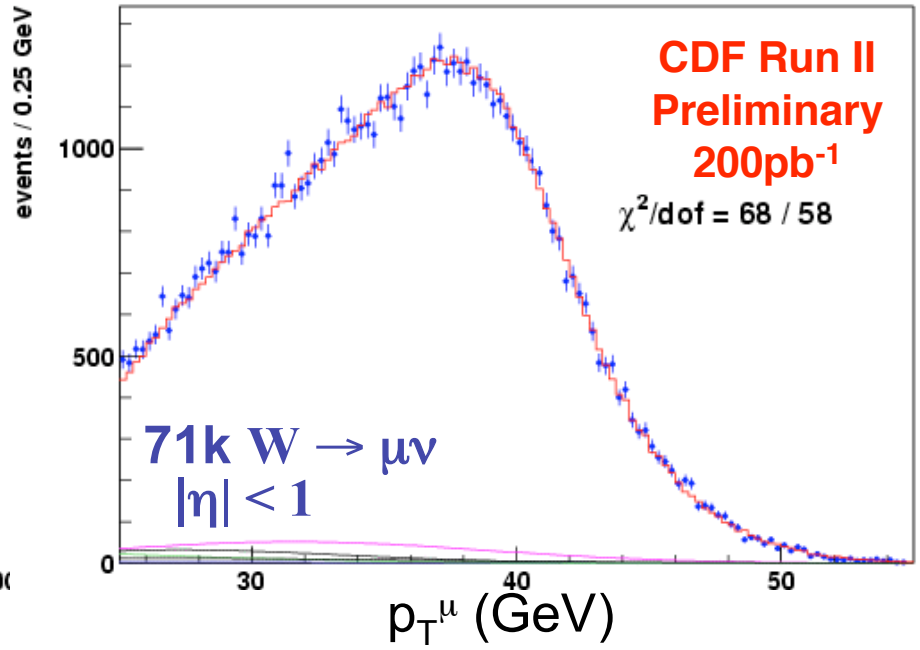
# Physics with Vector Bosons

- Publications:
  - 3 papers submitted or published
    - W & Z cross sections (e, $\mu$) - PRL
    - W$\gamma$ & Z$\gamma$ cross sections - PRL
    - Forward-Backward Asymmety in dielectron - PRD
  - 5 papers in publication review
    - ZZ+ZW cross section - PRD-RC
    - WW cross section - PRL
    - W Asymmetry
    - W & Z cross sections (e, $\mu$) - PRD
    - W Mass

# W Mass Measurement

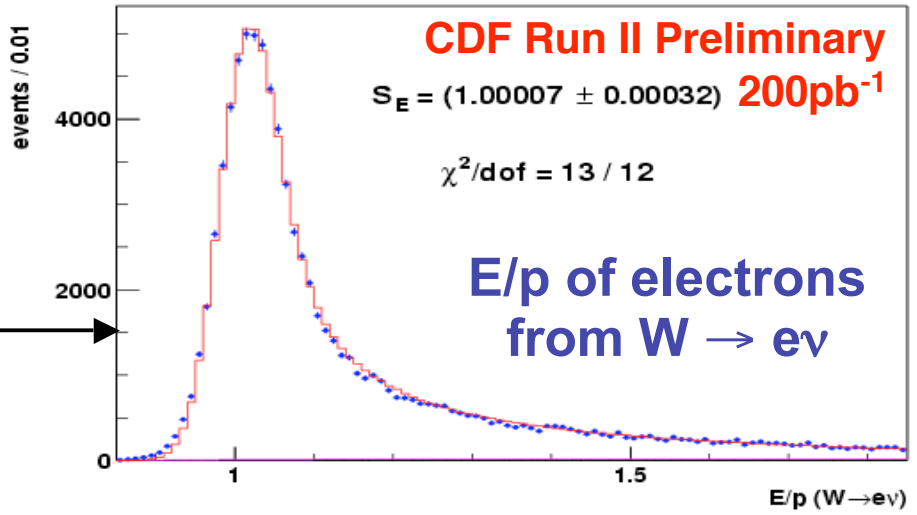



$$M_T = \sqrt{2E_T^{l}E_T^{\nu}(1-\cos\phi_{l\nu})} \quad \text{(GeV)}$$

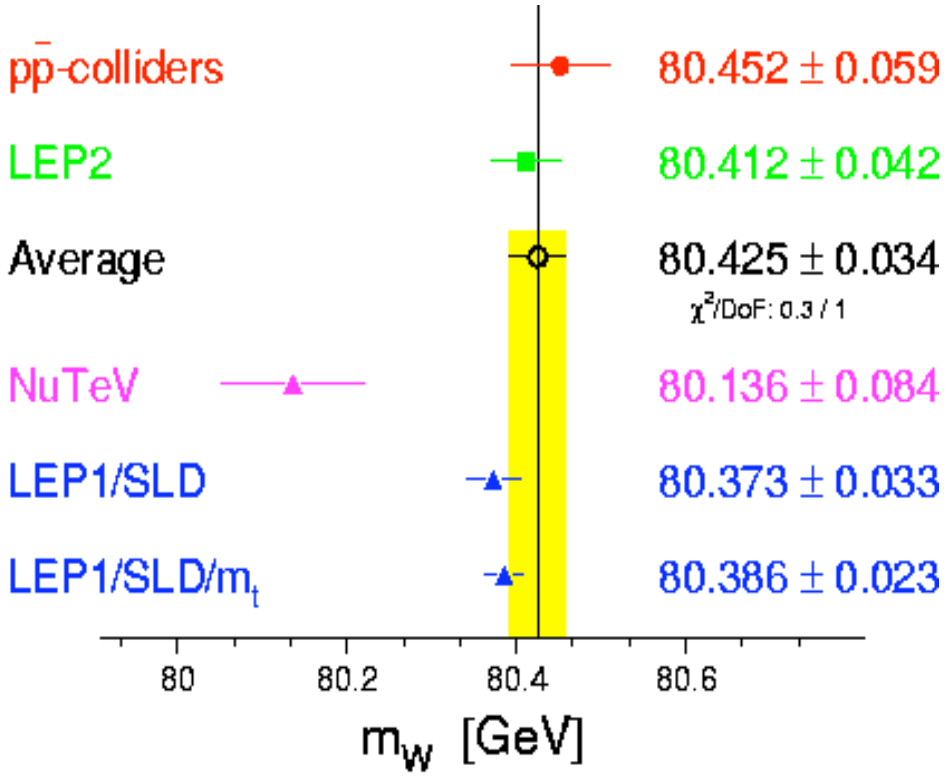



Statistical uncertainty ~ 35 MeV

Systematic uncertainty:
- Dominated by lepton E scale
- Most time and effort spent on detector calibration



# W Mass Measurement




| Experiment | $\Delta M_W$ |
|---|---|
| Run I Combined | 59 MeV |
| Run I CDF | 79 MeV |
| Run I D0 | 84 MeV |
| LEP-II Combined | 42 MeV |
| ALEPH (Single Best) | 58 MeV |

CDF Run II W Mass:

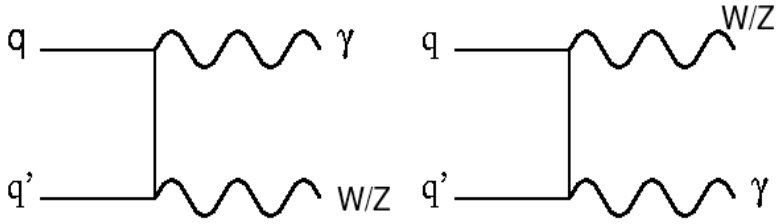
~76 MeV by this Winter (~200 $pb^{-1}$) - the level of Run I CDF uncertainty

~50 MeV by Summer 2005 (~360 $pb^{-1}$) - single best measurement

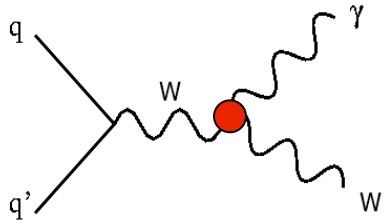
Under Godparents Review.

# Wγ, Zγ Production

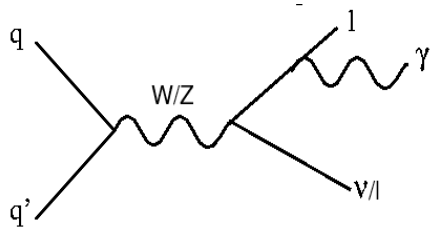
u- or t-channel

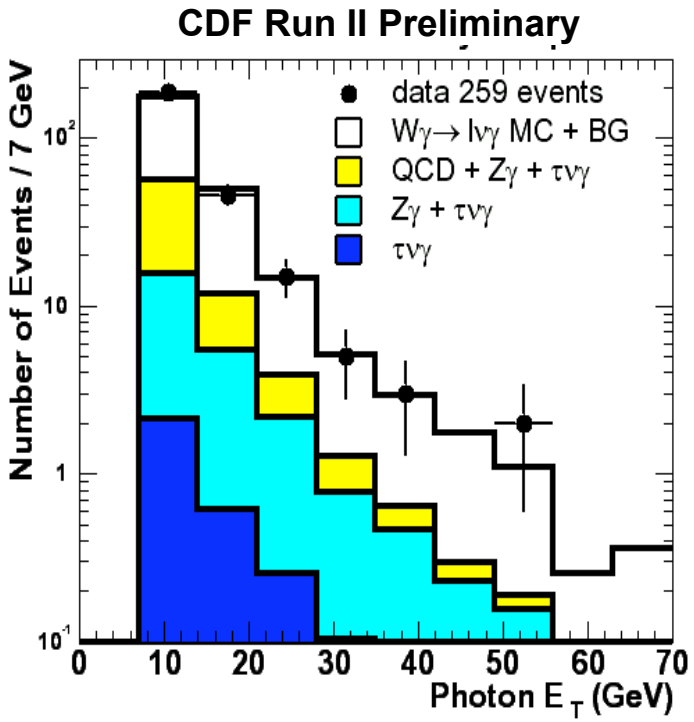


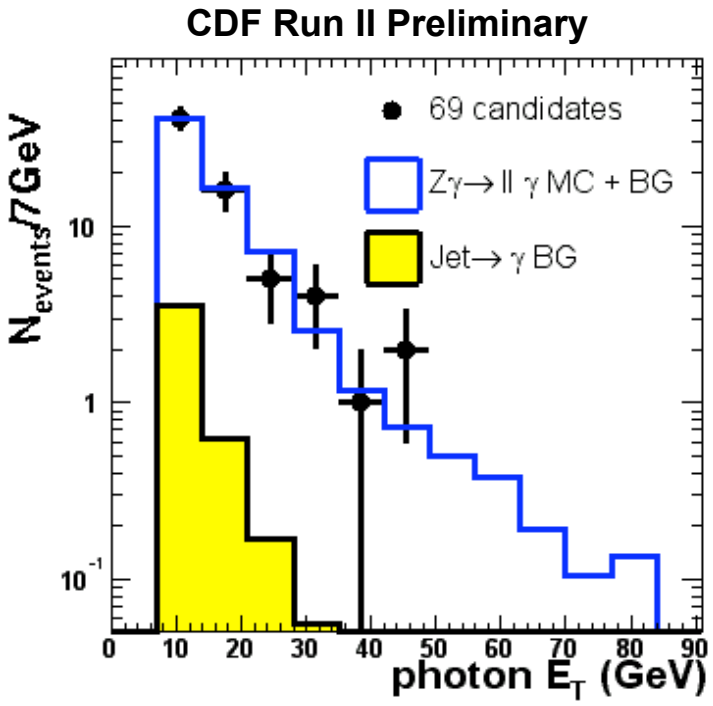

s-channel




final-state radiation

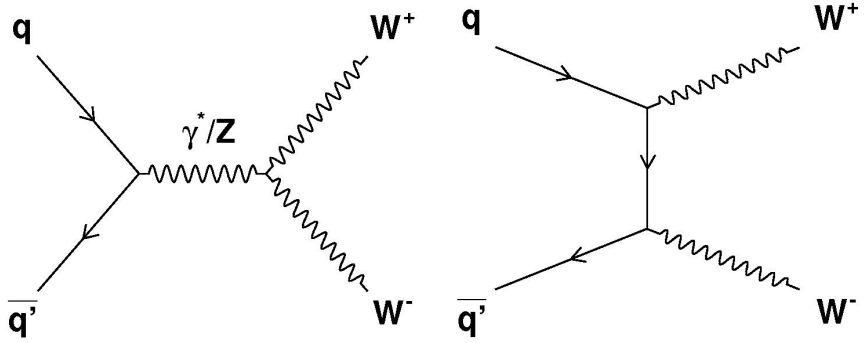


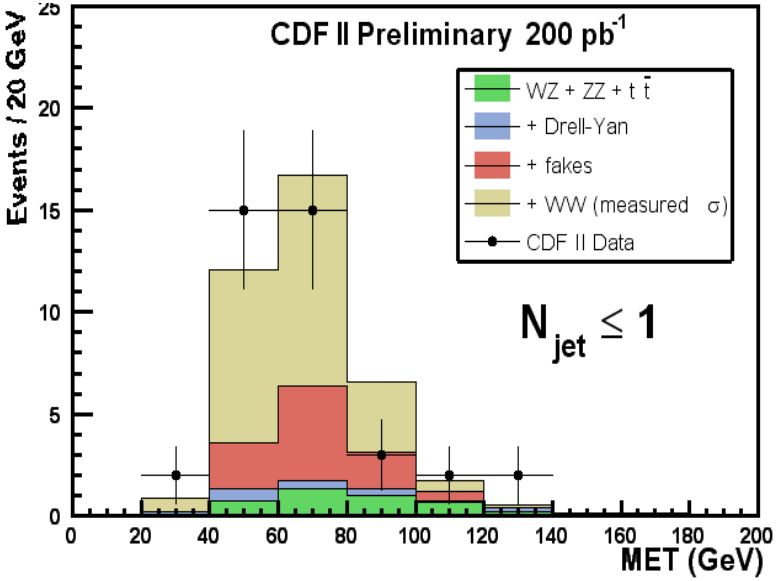



# WW, WZ, ZZ Production

- WW (SM 12.5 ± 0.8 pb)
  - Trilinear Gauge Coupling - hard to beat LEP (40k WW)
  - Tevatron can produce higher mass than LEP.
  - Important backgrounds to Higgs search (H -> WW)!




$$\sigma(WW) = 14.3 \pm^{5.6}_{4.9} \pm^{1.8}_{1.8} pb$$

- Still searching for WZ, ZZ (SM WW 5.2 ± 0.4 pb)

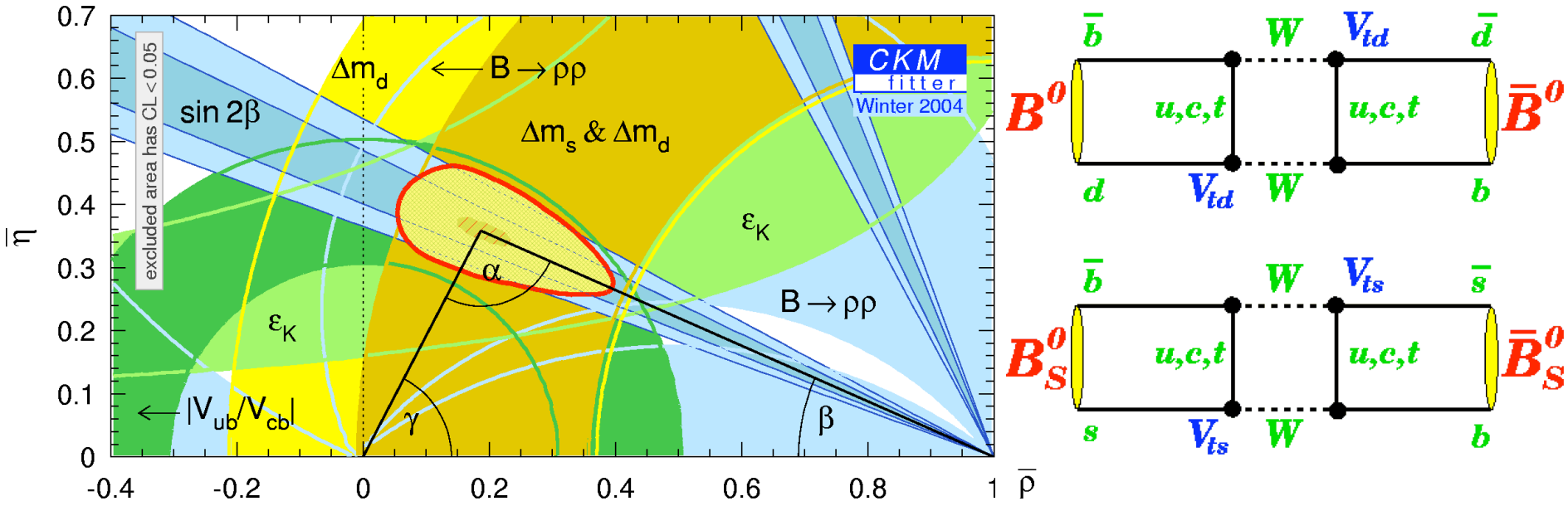
$$\sigma(WZ) < 13.9 pb @ 95\%\ C.L.$$

# Physics with Beauty and Charm Hadrons

- Publicationss:
  - 6 papers published or submitted
    - $D_s$, $D^+$ mass difference (Phys. Rev. D68, 072004, 2003)
    - Search for D -> $\mu\mu$ (Phys. Rev. D68, 091101, 2003)
    - Prompt Charm cross sections (Phys. Rev. Lett 91, 241804, 2003)
    - $B_d$, $B_s$ -> $\mu\mu$ (PRL 93, 032001, 2004)
    - Observation of X(3872) (Phys. Rev. Lett 93, 072001, 2004)
    - $D^*$ relative Br and CP asymmetry (submitted to Phys. Rev. Lett.)
  - 11 Papers in publication review
    - Pentaquark search
    - Inclusive J/$\psi$ cross section
    - B hadron masses (including $B_s$ and $\Lambda_b$)
    - Br of $\Lambda_b \rightarrow \Lambda_c \pi$
    - Ratio of Br($B^\pm \rightarrow J/\psi$ K) / Br($B^\pm \rightarrow J/\psi \pi$)
    - Hadronic moments in semileptonic B decays
    - B $\rightarrow$ hh and CP violation
    - .$\Lambda_b \rightarrow$ Kp, $\pi$p
    - Br of $B_s \rightarrow D_s \pi$
    - $B_s/B_0$ branching fraction ratio
    - $B_s$ lifetime difference

# B Physics

- Mixing
- CP Violation
- Rare Decays




**$B_s$ Mixing** World limit: $\Delta m_s > 14.4\ ps^{-1}$

SM pred.: $15 < \Delta m_s < 27\ ps^{-1}$ (99% probability)

# $B_s$ Mixing

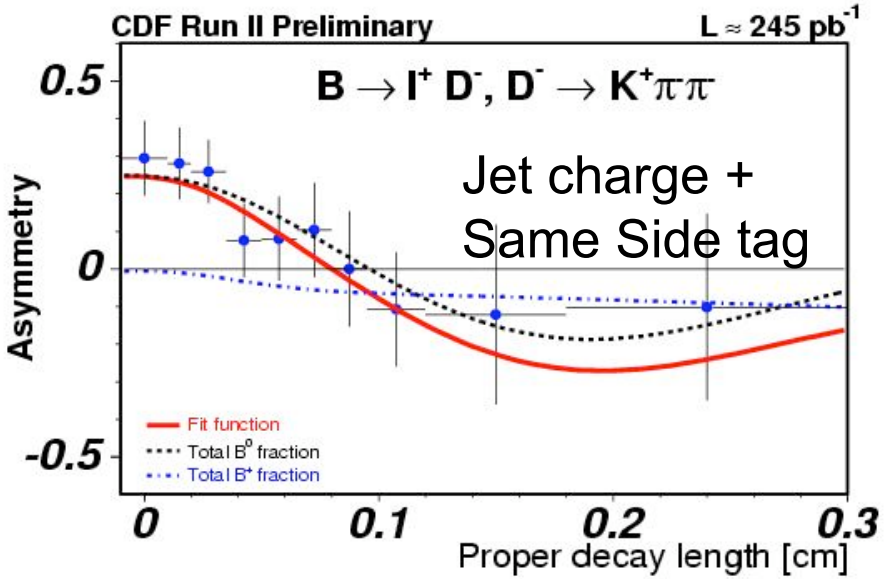
- Complex measurements involving many detector systems and analysis tools.
  - Triggering: optimized SVT algorithms
  - Exclusive reconstruction modes ($B_s \rightarrow D_s \pi$ + …)
  - Tagging ($\varepsilon D^2$): e, $\mu$, jet charge, same-side tag (Kaon), opposite-side tag (Kaon)
    - Involves TOF + dE/dx
  - Decay length resolution
    - Maximize L00 performance
- We have appointed $B_s$ Mixing coordinators - Bedeschi and Kroll
- 4 Internal workshops so far.
- Good progress on all fronts
  - e.g. $B_d$ mixing measurements in semileptonic and fully reconstructed modes
- Plan to present the first results on $B_s$ mixing by Summer 05

# $B_d$ Mixing Measurements

prepare machinery for $B_s$ mixing analysis

## semileptonic modes:

flavor (B or $\bar{B}$) tagging efficiency
at production $\varepsilon D^2 \sim$ 2-3% (CDF, D0)



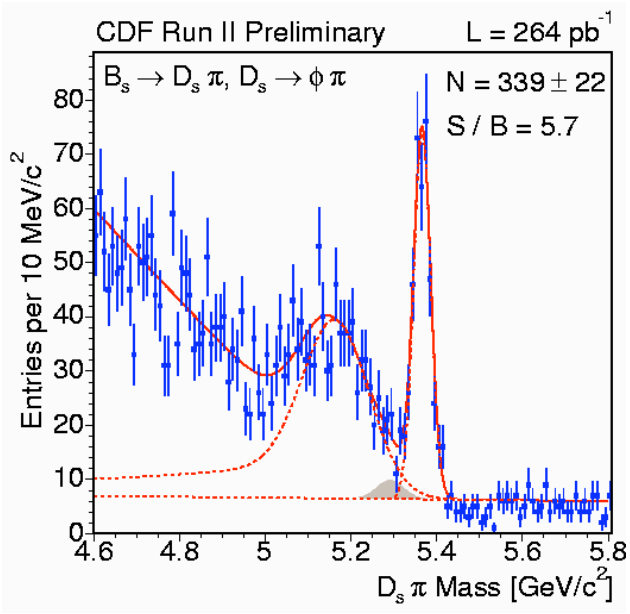

$\Delta m_d$(CDF) = 0.536 ± 0.037(stat) ± 0.017(syst) $pb^{-1}$

## fully reconstructed modes:

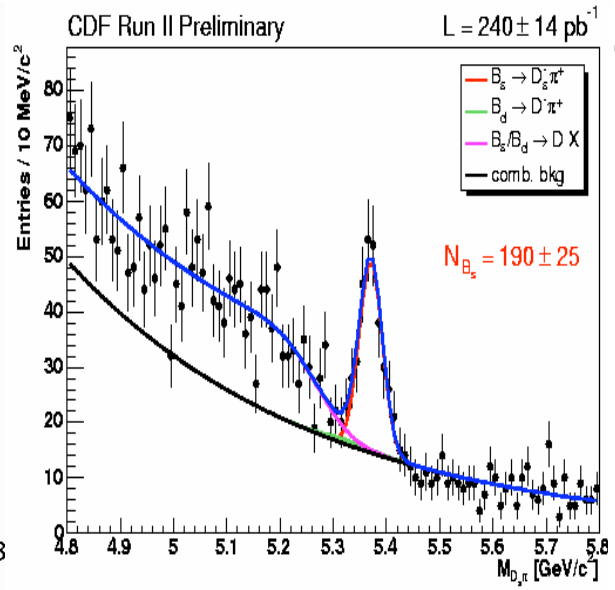
$B_d \rightarrow J/\psi\ K^{*0} \rightarrow \mu^+\mu^-\ K^+\pi^-$, $B_d \rightarrow D^-\pi^+$, $D^{*-}\pi^+$, $D^-\pi^+\pi^-\pi^+$, $D^{*-}\pi^+\pi^-\pi^+$

$\Delta m_d$ (CDF) = 0.526 ± 0.056(stat) ± 0.005(syst), $\varepsilon D^2 \sim$ 1%(SST)

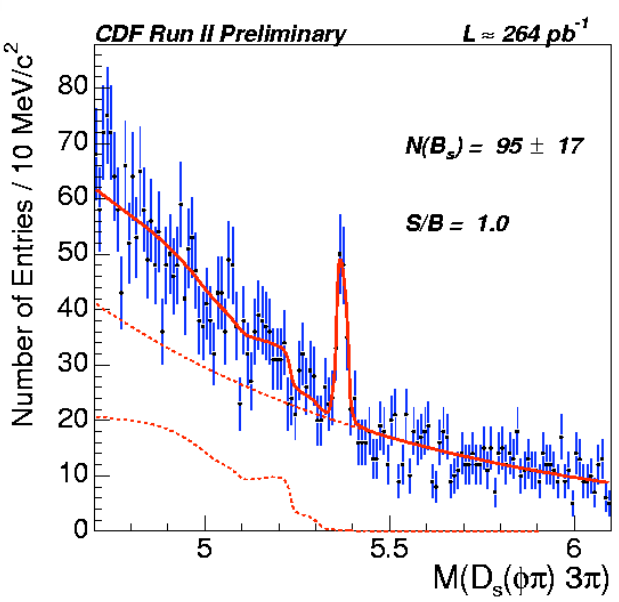
# $B_s$ Hadronic Signals




$B_s \to D_s\pi(D_s \to \phi\pi)$




$B_s \to D_s\pi(D_s \to K^*K)$



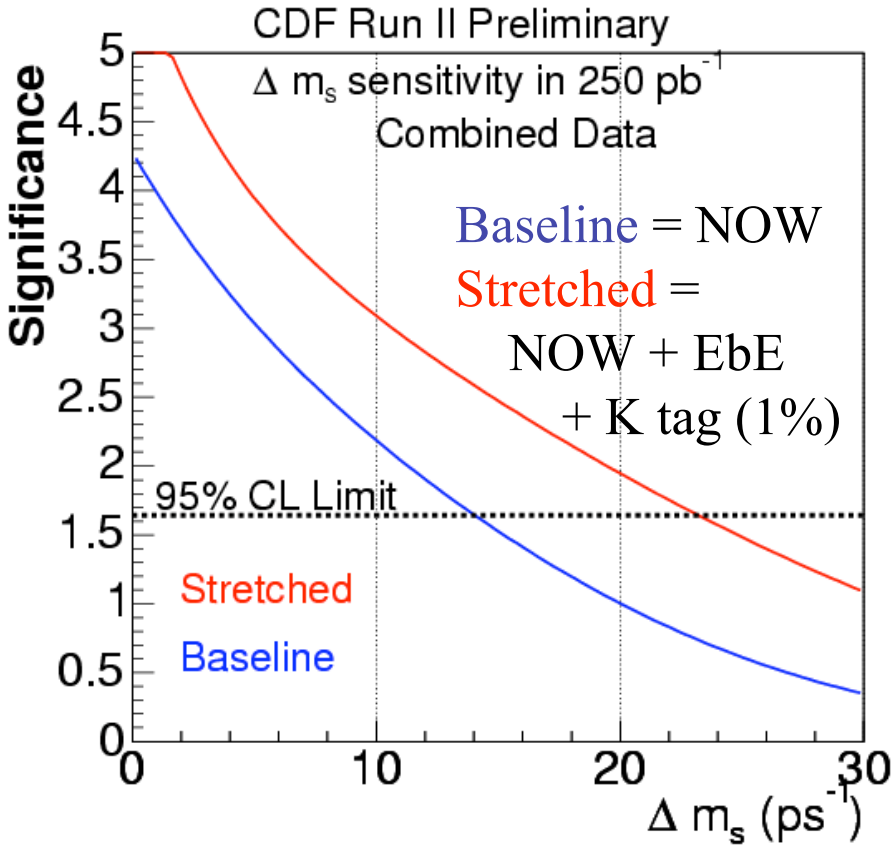

$B_s \to D_s 3\pi(D_s \to \phi\pi)$

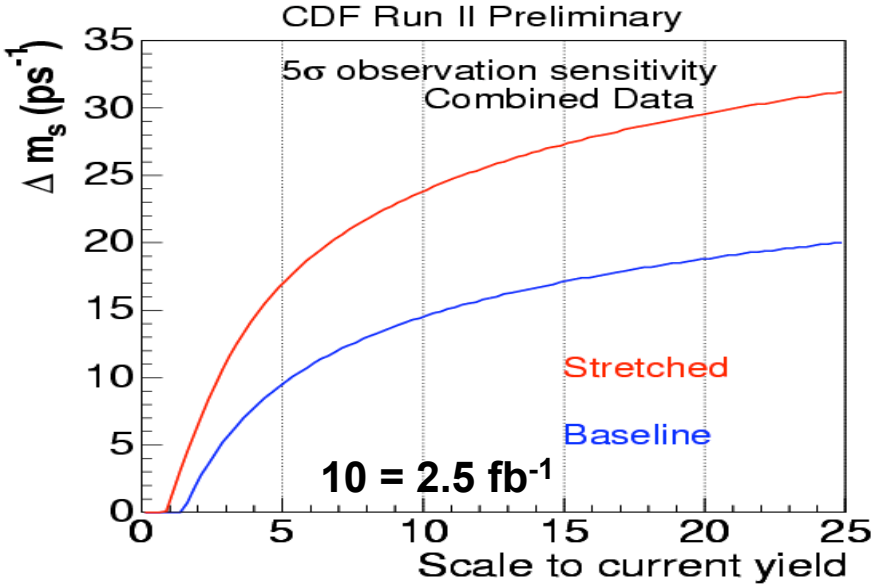
| Channel | Observed events | Luminosity (pb$^{-1}$) | Yield per 250 pb$^{-1}$ | S/B |
|---|---|---|---|---|
| $B_s \to D_s\pi(D_s \to \phi\pi)$ | $339 \pm 22$ | 264 | 320 | 5.7 |
| $B_s \to D_s 3\pi(D_s \to \phi\pi)$ | $95 \pm 17$ | 264 | 90 | 1.0 |
| $B_s \to D_s\pi(D_s \to K^*K)$ | $190 \pm 25$ | 240 | 200 | 1.3 |
| $B_s \to D_s\pi(D_s \to 3\pi)$ | $57 \pm 11$ | 124 | 115 | 1.75 |

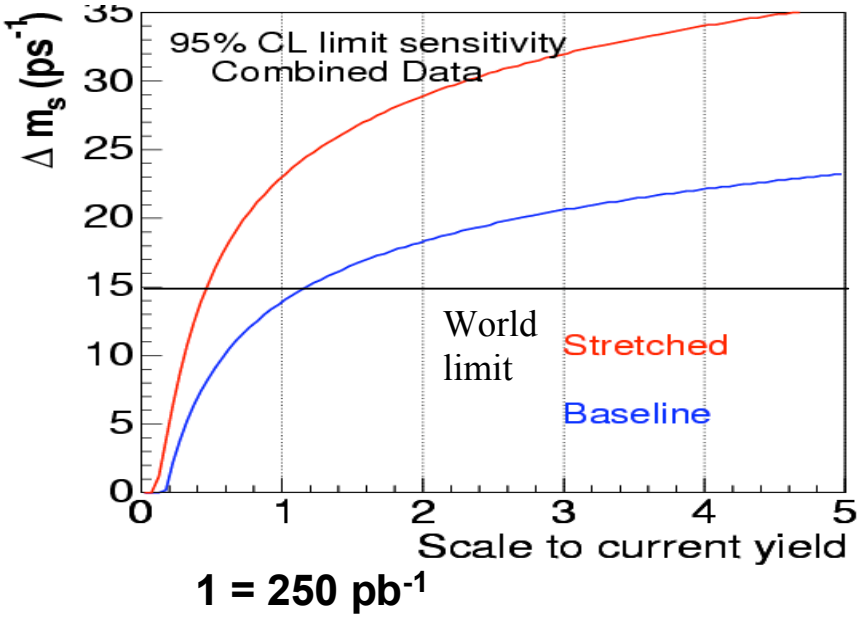
# Limit / Measurement of $B_s$ Oscillation

World limit: $\Delta m_s > 14.4\ ps^{-1}$

SM pred.: $15 < \Delta m_s < 27\ ps^{-1}$
(99% prob.)



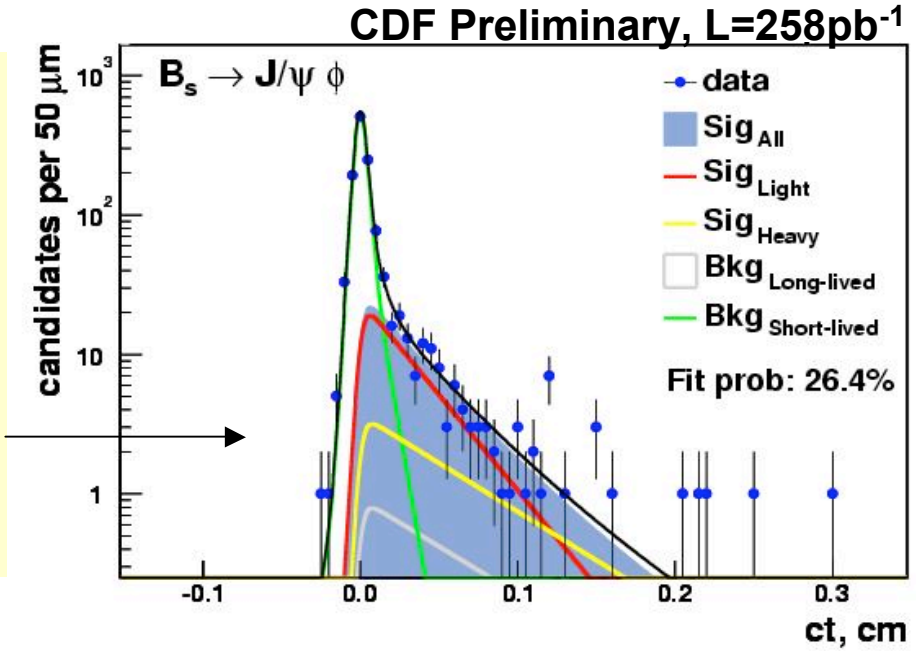
# $B_s \rightarrow J/\psi\,\phi$: $\Delta\Gamma_s$ and $\Delta m_s$

$\tau(B_s)$ = 1.37 ± 0.10 ± 0.01 ps

$\Delta\Gamma_s$ Lifetime difference ($\Delta\Gamma_s$) between $B_s$ eigenstates.
CP-odd($B_{heavy}$) and CP-even($B_{light}$) have different angular distributions.

SM:
$\Delta\Gamma_s / \Gamma_s$ (SM) = 0.12 ± 0.06
(hep-ph/0012219)

CDF:
$\Delta\Gamma_s$ = 0.46 ± 0.18 ± 0.01 ps$^{-1}$
$\Delta\Gamma_s / \Gamma_s = 0.71\ ^{+0.24}_{-0.28} \pm 0.01$
(with $\Gamma_s = \Gamma_d$ constraint)



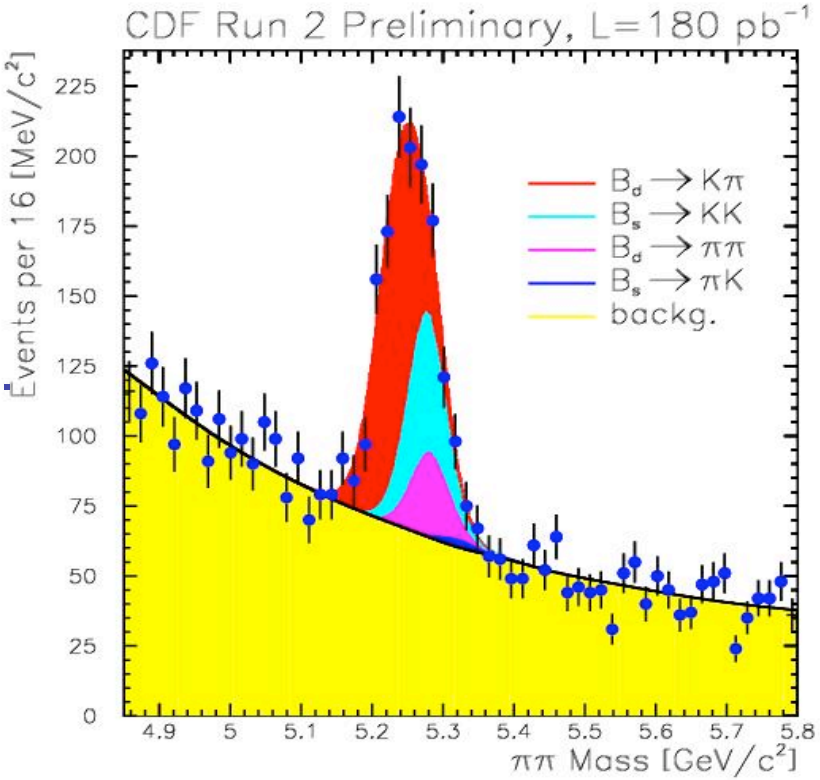

$\Delta m_s$ To first approx: $\Delta\Gamma_s / \Delta m_s = 1.5\pi\, m_b^2 / m_t^2 = 3.7\ ^{+0.8}_{-1.5} \times 10^{-3}$
(see Beneke et al. for full form NLO analysis, hep-ph/9808385)

$\Delta m_s$ (indirect) = 125 $^{+69}_{-55}$ ps$^{-1}$ (SM 99%: 15 < $\Delta m_s$ < 27 ps$^{-1}$)

# Charmless B Decays $B_{s,d} \to h^+h^-$

- ***$B_{s,d} \to h^+h^-$***
  - $B_d \to \pi\pi$ (CPA from B factories) and $Br(B_s \to KK)$ from CDF: sensitive to CP angle $\gamma$ (Fleischer)
  - $B_{d,s} \to \pi\pi$, $K\pi$, KK: statistical separation by kinematics & particle ID.

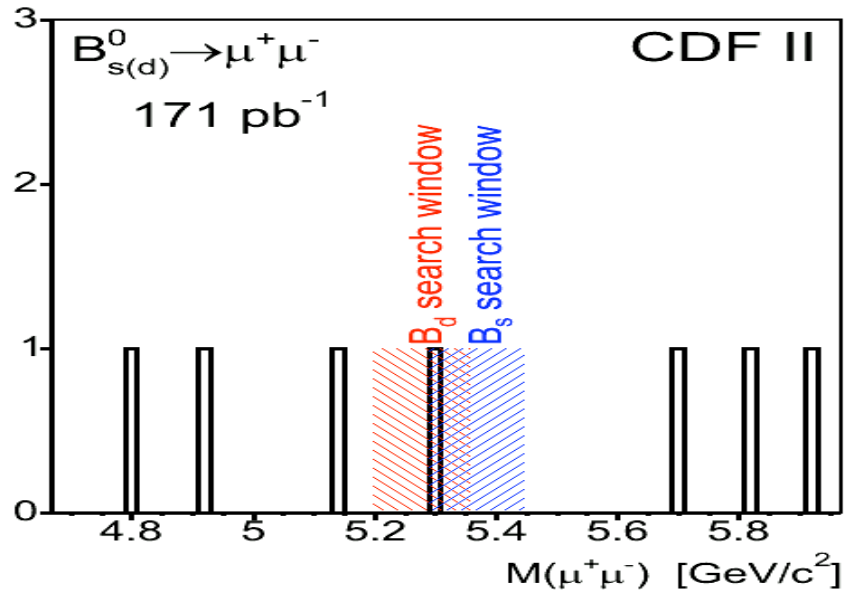
| | | |
|---|---|---|
| $B^0 \to \pi\pi$ | 134 | 15% |
| $B^0 \to K\pi$ | 509 | 57% |
| $B_s \to KK$ | 232 | 26% |
| $B_s \to K\pi$ | 18 | 2% |

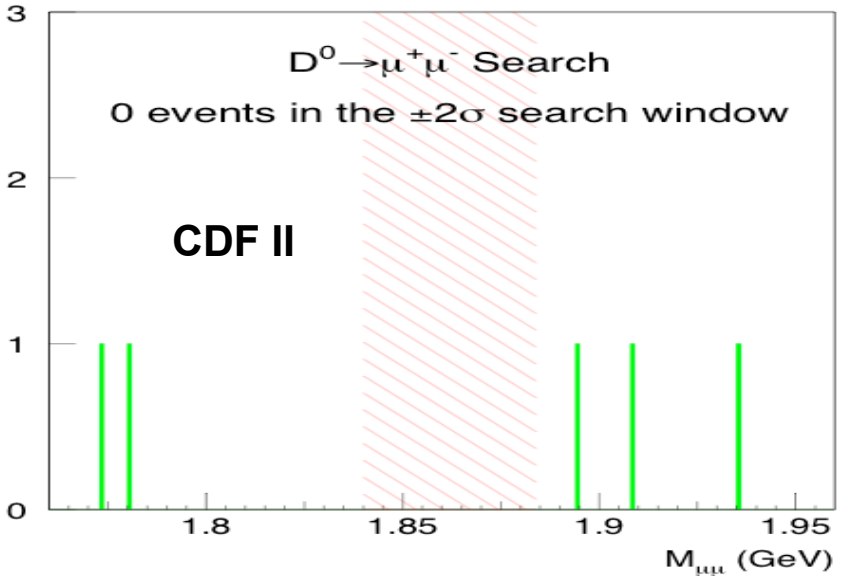



$A_{CP} = [N(B_d \to K^-\pi^+) - N(B_d \to K^+\pi^-)] / N(B_d \to K^-\pi^+, K^+\pi^-)$
$= -0.04 \pm 0.08 \pm 0.01$ (L = 180 pb$^{-1}$)

$A_{CP}^{BaBar} = -0.133 \pm 0.030 \pm 0.009$, $A_{CP}^{Belle} = -0.101 \pm 0.025 \pm 0.005$

# $B_s$, $B_d$, $D^0 \rightarrow \mu^+\mu^-$




SM expectations:

$Br(B_s \rightarrow \mu\mu) \sim 3.5 \times 10^{-9}$

$Br(D^0 \rightarrow \mu\mu) \sim 10^{-13}$

SUSY: $Br(B_s \rightarrow \mu\mu) \sim \tan^6\beta$

Can be enhanced by 10-1000.

e.g. $\tan\beta \sim 40$ for $Br \sim 10^{-7}$

95% CL $\mu^+\mu^-$ Br limits:

$B_s$ : $7.5 \times 10^{-7}$ (unique to Tevatron)

$B_d$ : $1.9 \times 10^{-7}$

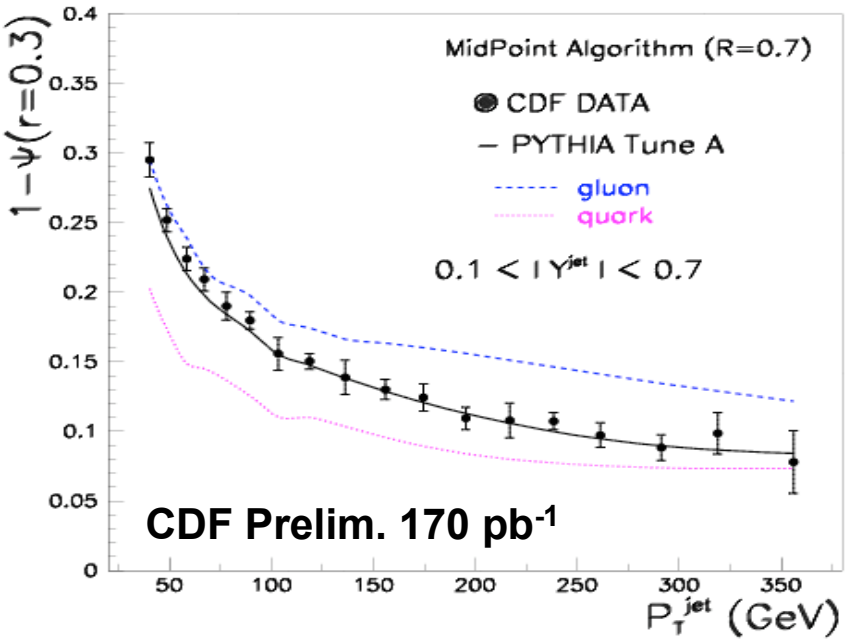
$D^0$ : $2.5 \times 10^{-6}$

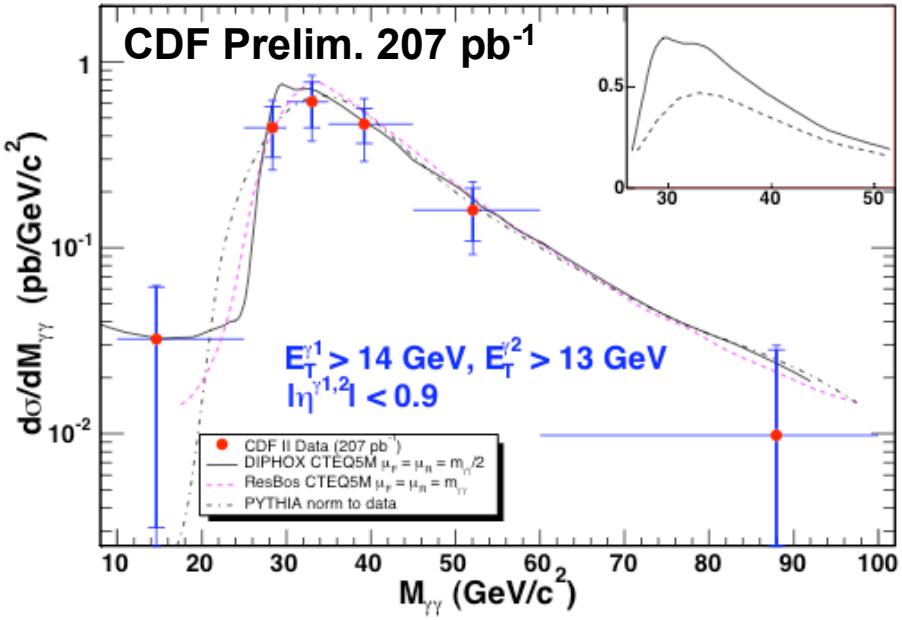
Excludes $SO_{10}$ space(hep-ph/0304101), large parts of R-parity violating SUSY. Smaller exclusion in mSUGRA MSSM

Improved limits with full data sample by this winter.

# QCD Physics

- Publications:
  - 2 papers godparent pub. review
    - Jet shape analysis
    - Di-photon cross section




Jet shapes and Energy flows in jets:
Constrain phenomenological models
Describing soft-gluon rad and undelying
Event in hadron collisions.
• Pythia + Tune A describes data well.

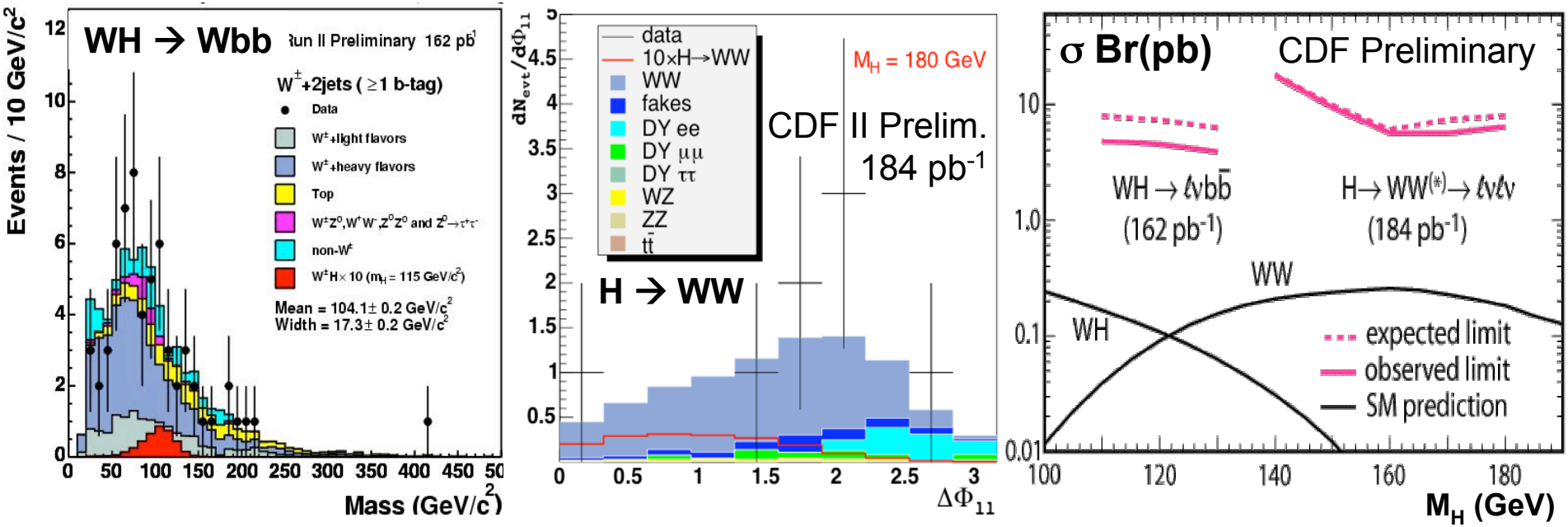
QCD test, Background for
Potential new physics processes
• Pythia disagrees by x2
• Require resummed full NLO

# New Particle and Phenomena Searches

- Publications:
  - 4 paper published or submitted
    - $H^{++}$ -> ee, $\mu\mu$, $e\mu$ (PRL accepted)
    - $e^*$ -> $e\gamma$ (submitted to PRL)
    - Diphoton + missing $E_T$ (submitted to PRD)
    - Search for leptoquarks in jets + missing $E_T$ (submitted to PRL)
  - 9 papers in publication review
    - Search for Z' -> ee, $\mu\mu$ (high mass dilepton)
    - Search for W' -> $e\nu$
    - Search for 1st and 2nd generation leptoquarks
    - Stable $H^{++}$ search
    - WH -> Wbb Standard Model Higgs search
    - WH -> WWW* Standard Model Higgs search
    - H -> WW Standard Model Higgs search
    - Gluino / Stottom search
    - Monopole search

# Standard Model Higgs Search

$M_H$ < 130 GeV: W,Z + H (→ bb), $M_H$ > 130 GeV: H → WW



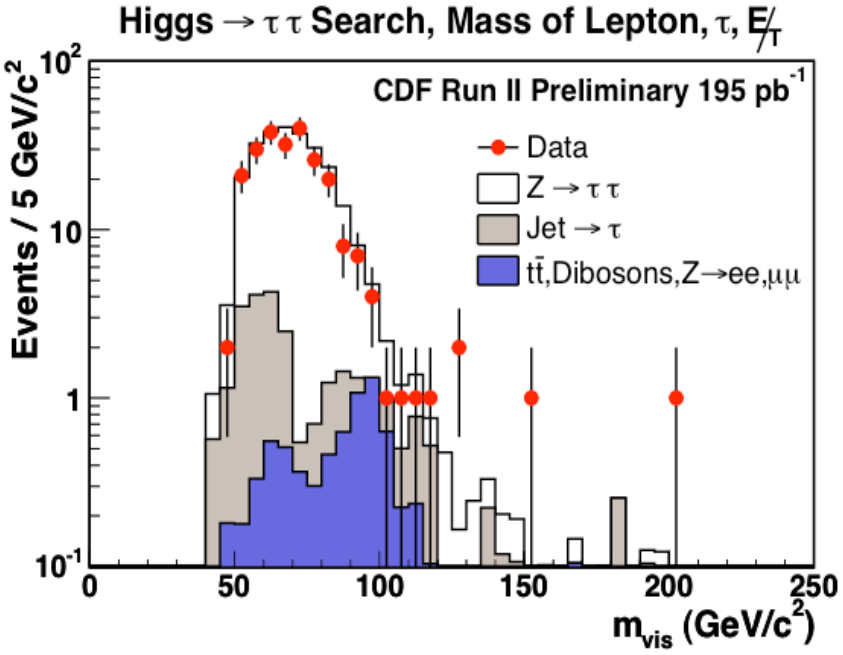

- SM: Limits already exceeding Run I results.
  Sensitivity beyond LEP exclusion starts at ~2 $fb^{-1}$.
- New Physics: Interesting sensitivity to other new physics sooner?
- Improvements expected from
  - Better *b* tagging, topological (spin 0) information, more channels(ZH), better mass resolution (Z → bb sample)

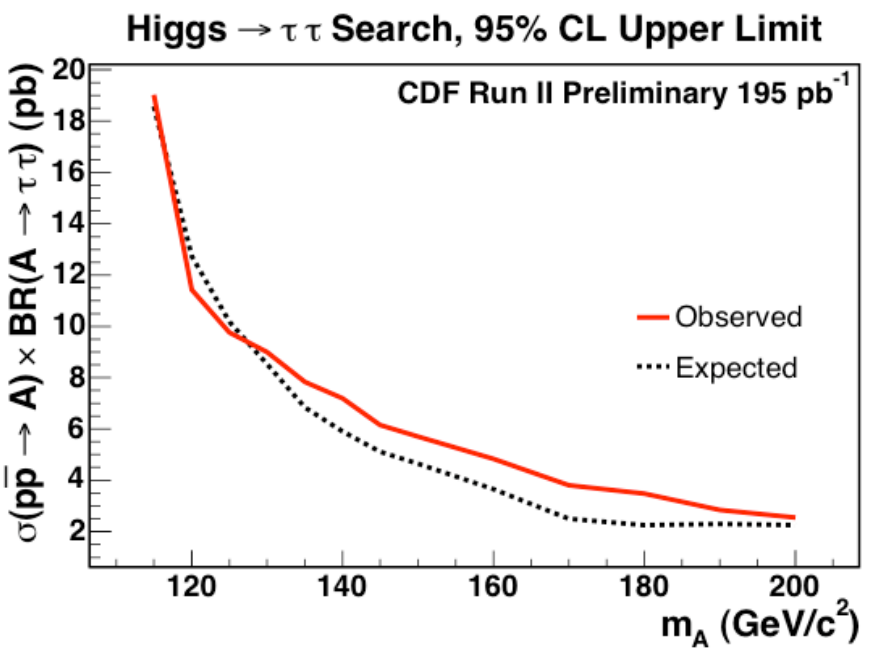
# MSSM Higgs Search

at high tanβ:

- enhanced x-sections
- heavy flavor (b, τ) preferred

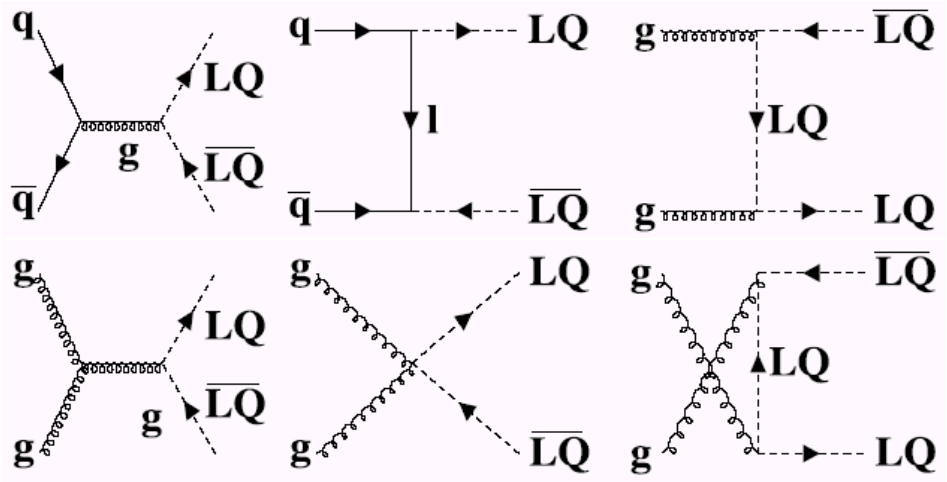
**$\phi$ (from gg or qq) or $bb\phi$ production with $\phi \rightarrow \tau\tau$**

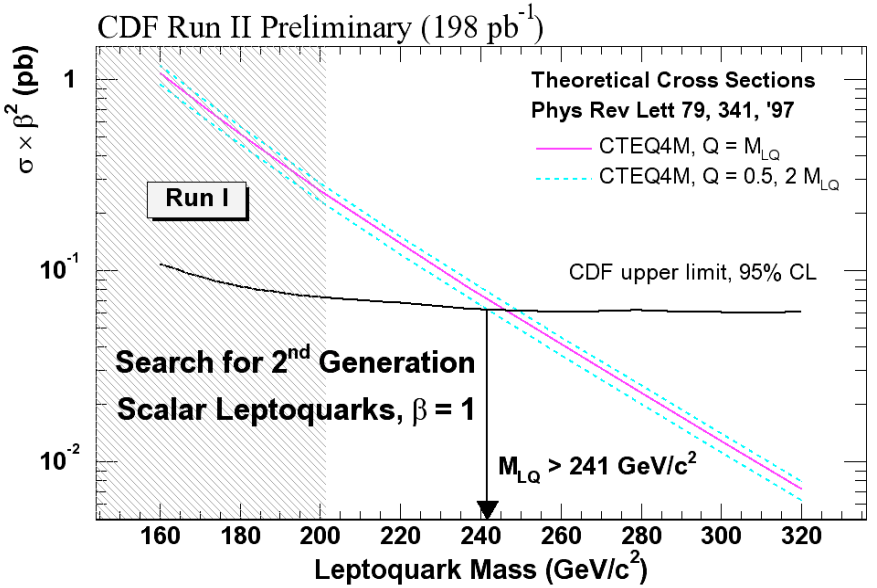


# Leptoquarks

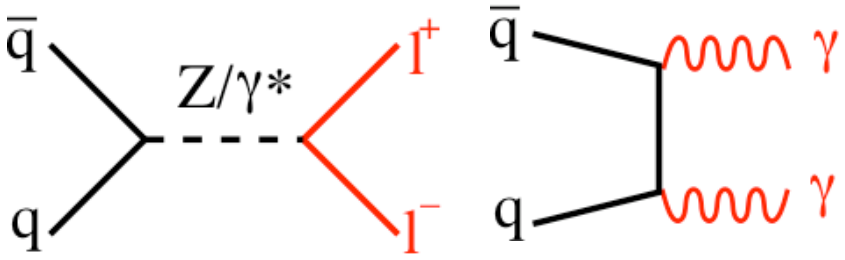
- Leptoquarks appear in many SM extensions.
  - LQ carry both lepton and baryon number
- Limits
  - First generation:
    - $LQ_1 \rightarrow eq$ (100%)
      - 230 GeV at 95% CL
    - $LQ_1 \rightarrow eq$ (50%)
      - 176 GeV at 95% CL
  - Second generation:
    - $LQ_2 \rightarrow \mu q$ (100%)
      - 241 GeV at 95% CL
  - Generation independent:
    - $LQ_1 \rightarrow \nu q$ (100%)
      - 78-117 GeV excluded



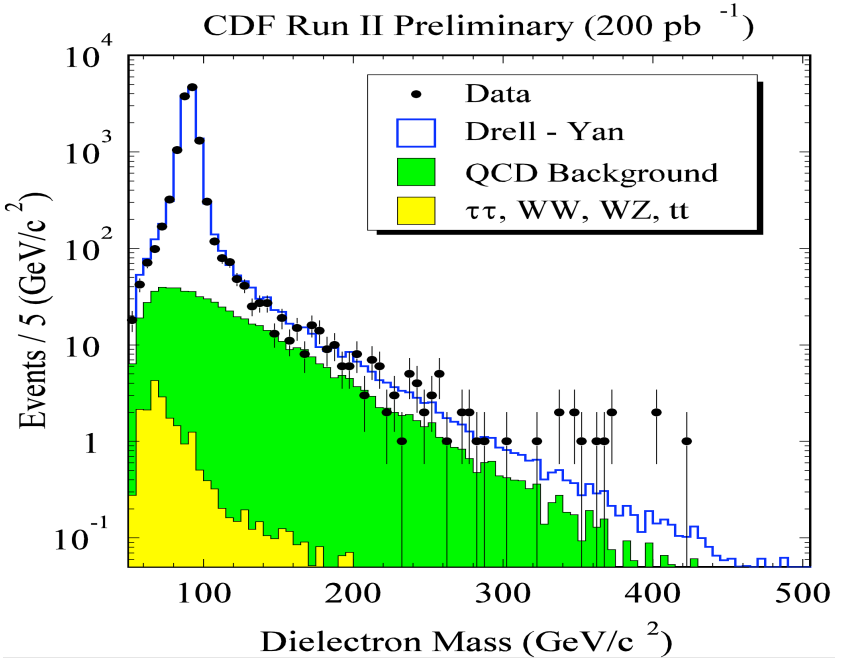
# Very High $P_T$ Physics

## SM High Mass Production:




## New Physics at high mass:

- Resonance Signature
  - Spin-1: Z'
  - Spin-2: Randall-Sundrum (RS) Graviton
- Tail Enhancement
  - Large Extra Dimensions: Arkani-Hamed, Dimopoulos, Dvali (ADD)
  - Contact interaction



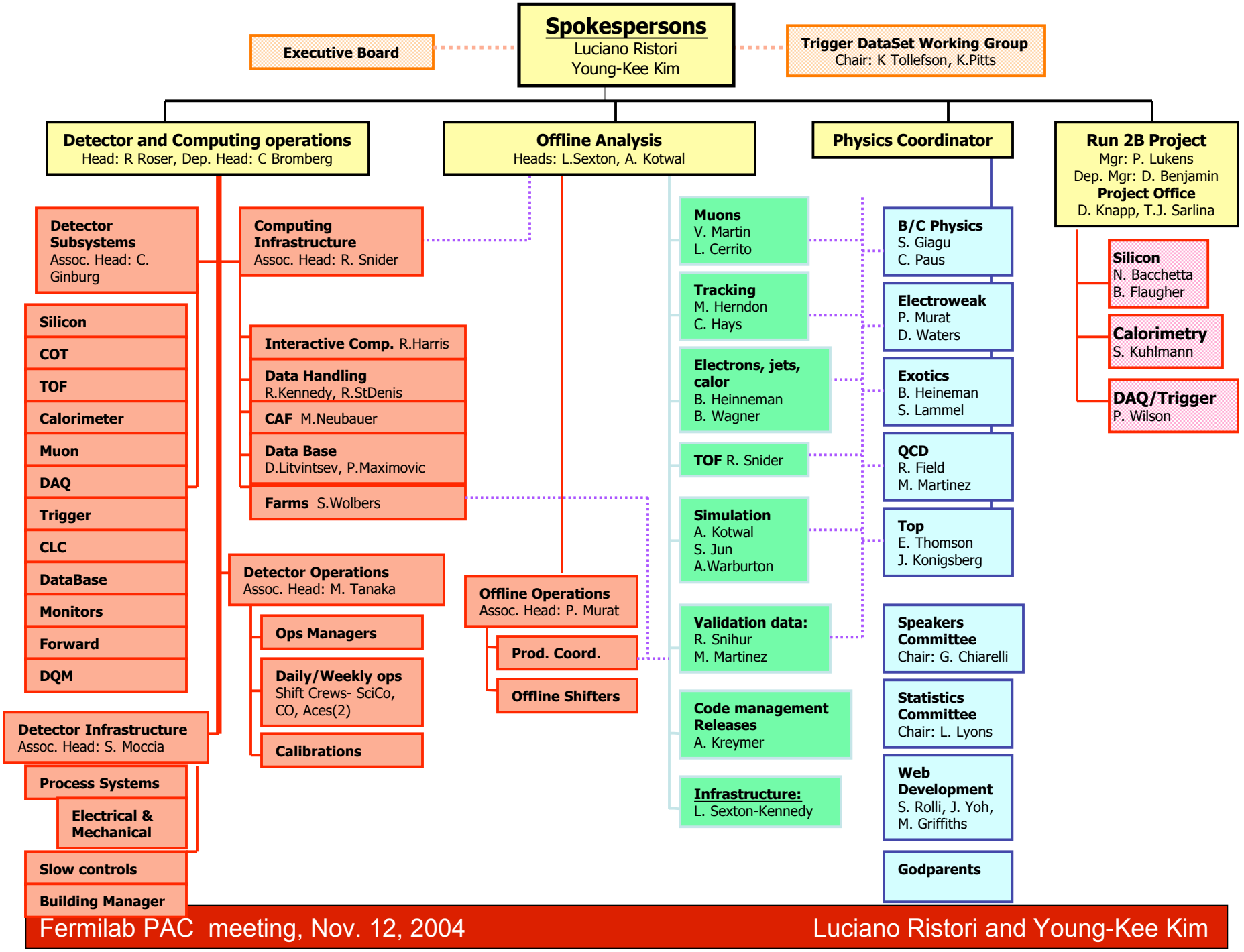

Z' by CDF with ee + μμ

(815 GeV w/ SM decays)

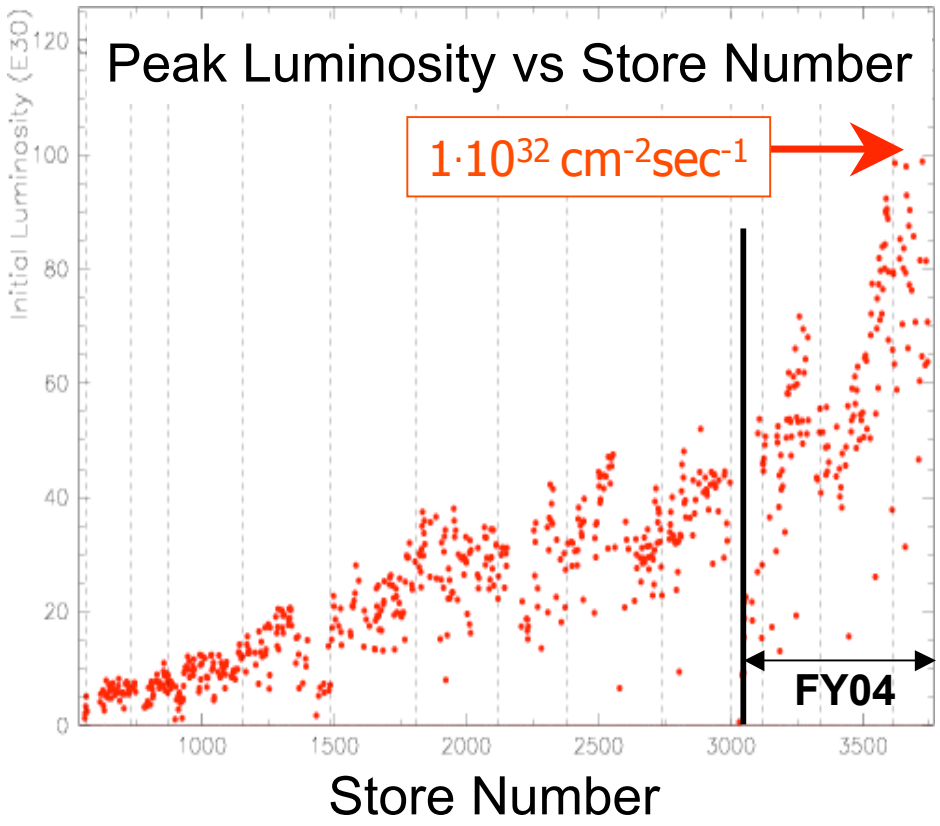
# Conclusions

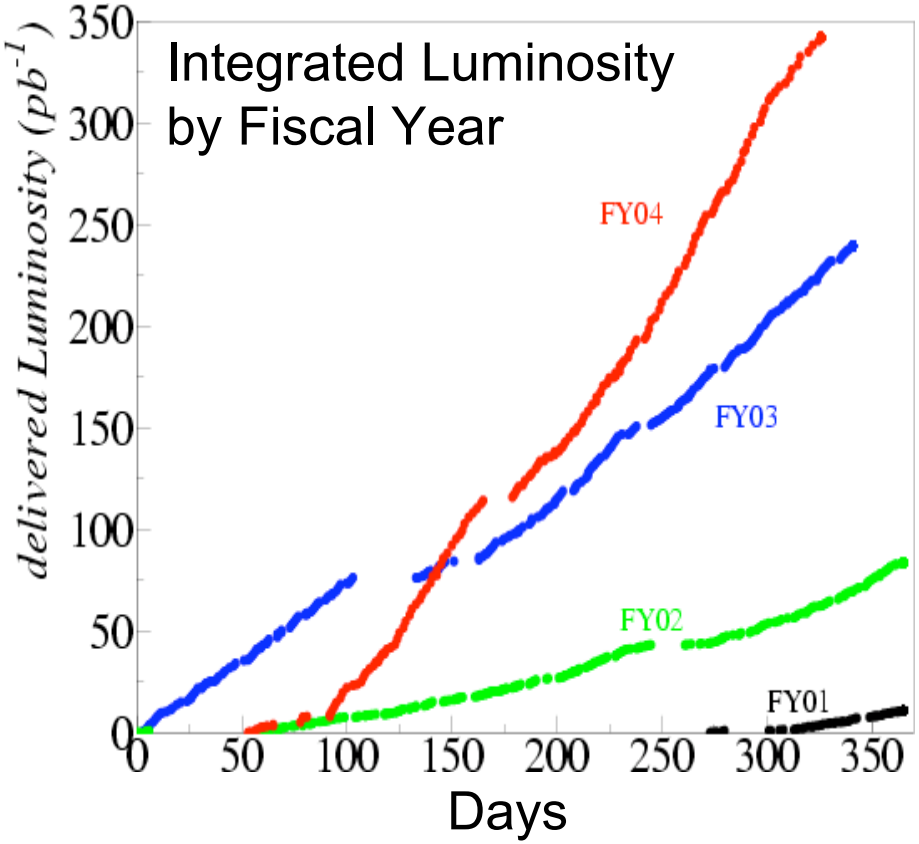
- Detectors
  - CDF detectors are performing well.
  - Triggers & DAQ - continuously improving
- Data analysis
  - Producing many physics results. Publications from all physics groups - making good progress
  - currently analyzing ~400 $pb^{-1}$ data (4 x Run I data)
    - Summer 2003 results with ~100 $pb^{-1}$
    - Summer 2004 results with ~200 $pb^{-1}$
    - Expect Summer 2005 results with ~400 $pb^{-1}$
  - understanding detectors and backgrounds
  - developing and optimizing physics algorithms
  - much better measurements will come soon.
- Coming year
  - Double the data again by summer 2005 hopefully (8 x Run I)
  - Opportunity for discovery good with new confident in luminosity.

# Back-Up Slides


Spokespersons
Luciano Ristori
Young-Kee Kim
Executive Board
Trigger DataSet Working Group
Chair: K Tollefson, K.Pitts
Detector and Computing operations
Head: R Roser, Dep. Head: C Bromberg
Offline Analysis
Heads: L.Sexton, A. Kotwal
Physics Coordinator
Run 2B Project
Mgr: P. Lukens
Dep. Mgr: D. Benjamin
Project Office
D. Knapp, T.J. Sarlina
Detector Subsystems
Assoc. Head: C. Ginburg
Silicon
COT
TOF
Calorimeter
Muon
DAQ
Trigger
CLC
DataBase
Monitors
Forward
DQM
Computing Infrastructure
Assoc. Head: R. Snider
Interactive Comp. R.Harris
Data Handling
R.Kennedy, R.StDenis
CAF M.Neubauer
Data Base
D.Litvintsev, P.Maximovic
Farms S.Wolbers
Detector Operations
Assoc. Head: M. Tanaka
Ops Managers
Daily/Weekly ops
Shift Crews- SciCo, CO, Aces(2)
Calibrations
Detector Infrastructure
Assoc. Head: S. Moccia
Process Systems
Electrical & Mechanical
Slow controls
Building Manager
Offline Operations
Assoc. Head: P. Murat
Prod. Coord.
Offline Shifters
Muons
V. Martin
L. Cerrito
Tracking
M. Herndon
C. Hays
Electrons, jets, calor
B. Heinneman
B. Wagner
TOF R. Snider
Simulation
A. Kotwal
S. Jun
A.Warburton
Validation data:
R. Snihur
M. Martinez
Code management Releases
A. Kreymer
Infrastructure:
L. Sexton-Kennedy
B/C Physics
S. Giagu
C. Paus
Electroweak
P. Murat
D. Waters
Exotics
B. Heineman
S. Lammel
QCD
R. Field
M. Martinez
Top
E. Thomson
J. Konigsberg
Speakers Committee
Chair: G. Chiarelli
Statistics Committee
Chair: L. Lyons
Web Development
S. Rolli, J. Yoh, M. Griffiths
Godparents
Silicon
N. Bacchetta
B. Flaugher
Calorimetry
S. Kuhlmann
DAQ/Trigger
P. Wilson

# Accelerator Performance



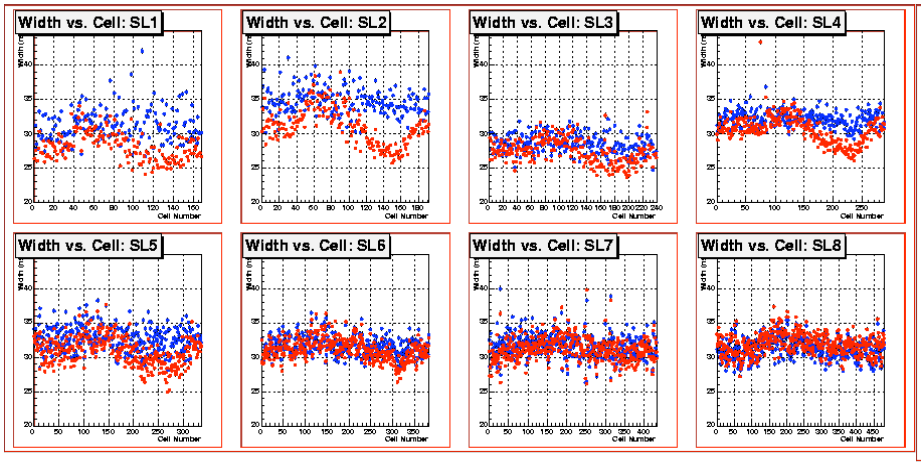

Peak luminosity > $10^{32}$ cm$^{-2}$ sec$^{-1}$
Total ~0.68 fb$^{-1}$ delivered so far

Note that FY04 had substantially fewer weeks of Accelerator operations than FY03.

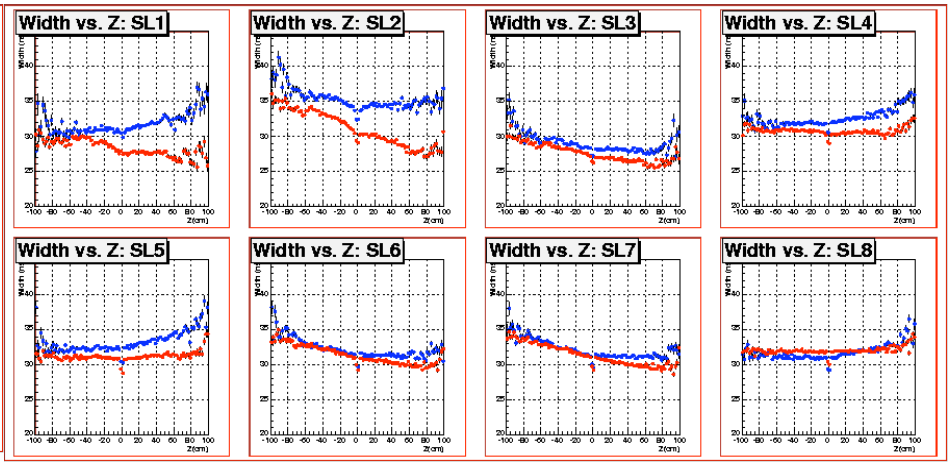
# Gain Loss of the CDF Outer Tracker (COT)

- COT experienced significant gain loss - up to x2 loss in gain that is both *r*, $\phi$ and *z* dependent.
- Degradation source comes from hydrocarbons coating “sense” wires.
- Turned parts of COT off and reduced HV on other sections of COT while we investigated the problem to prevent further damage - in case the process was irreversible. (Compromised COT performance Period)
- B physics program suffered during this period due to trigger track fakes
- Formed an international committee of chamber experts to advice CDF, chaired by R. Kephart.

**Pulse Width vs Phi for each SL**

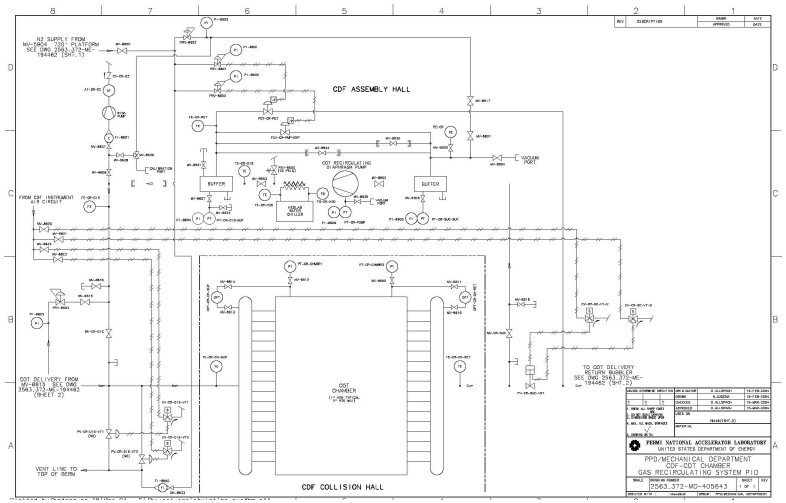


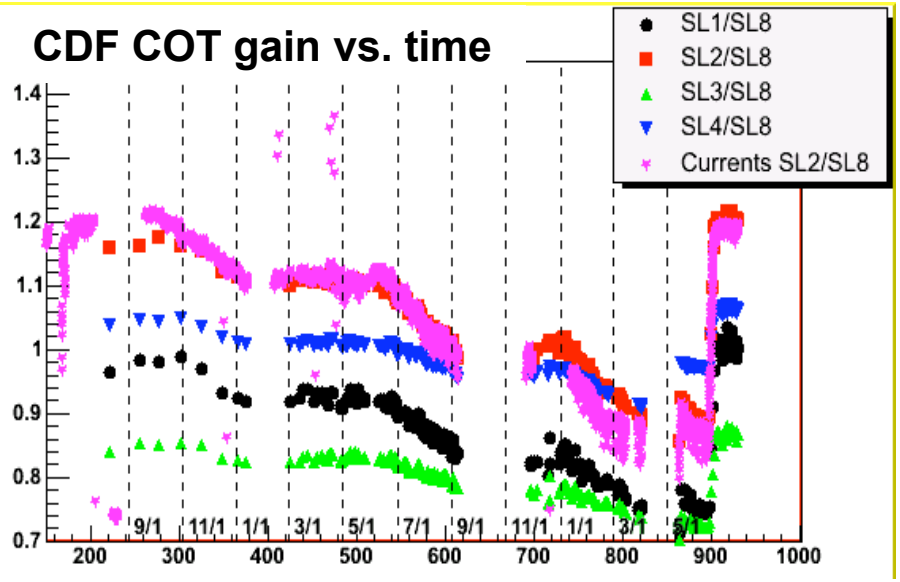

**Pulse Width vs Z for each SL**



# The Solution for the COT Gain Loss

- Built a gas recirculation system in order to move gas through the chamber x10 faster than before.
- During this installation, observed gain recovery (a small amount of air enters the chamber). Control experiment with air confirmed gain recovery.
- Used the recirculation system to add air and then **Oxygen**.
- Chamber is now fully recovered (late May, 2004).
- 85 $pb^{-1}$ of date collected with compromised chamber.

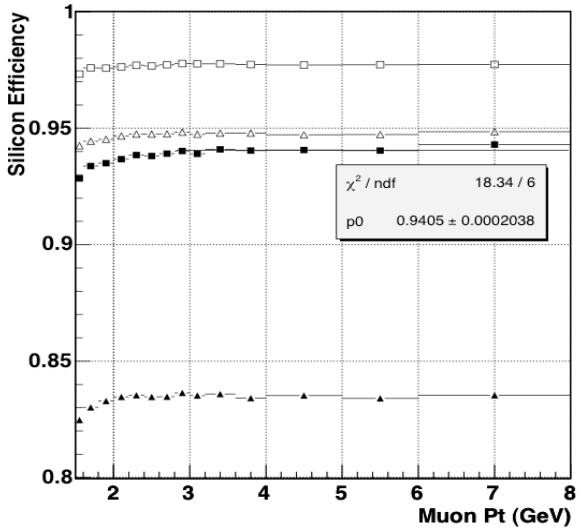


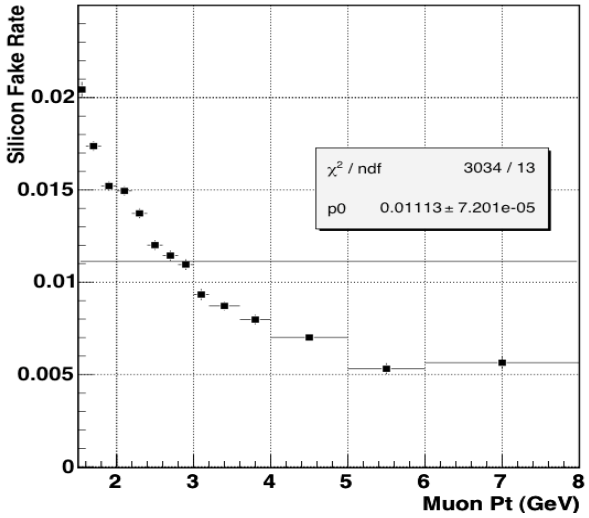



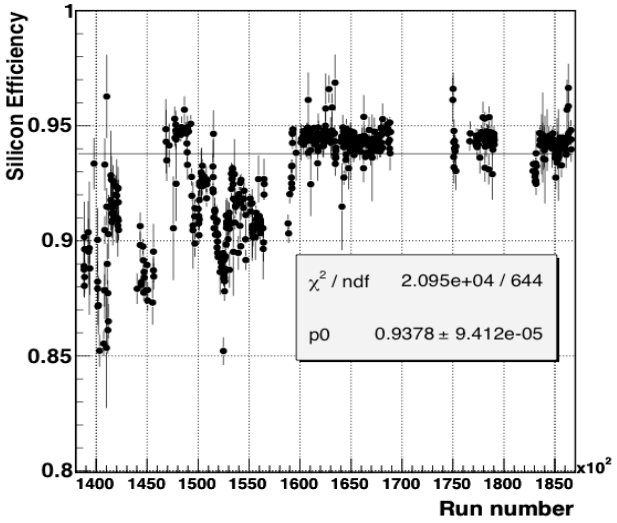

**Feb.2002** **Aug.2004**

# Silicon Tracking

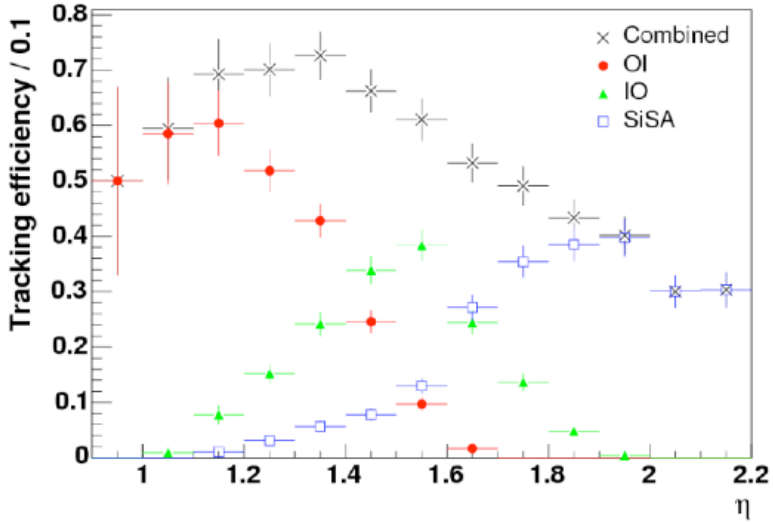
SVX II 3-hit efficiency and fake rate for tracks in the COT fiducial

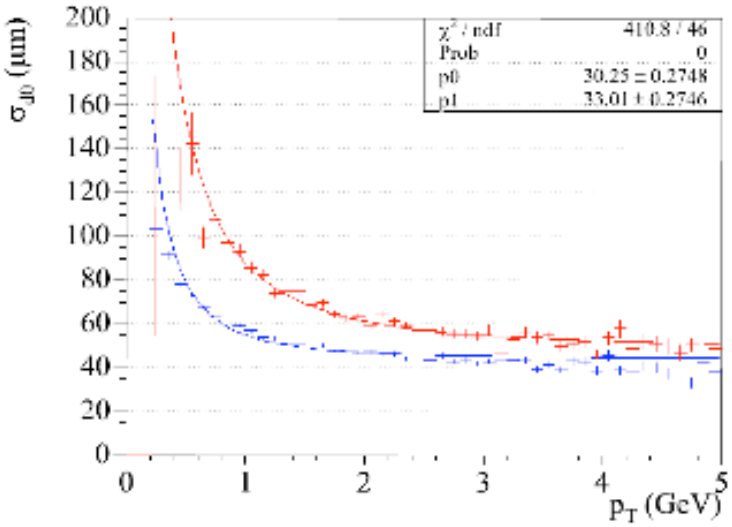



Adding ISL and L00



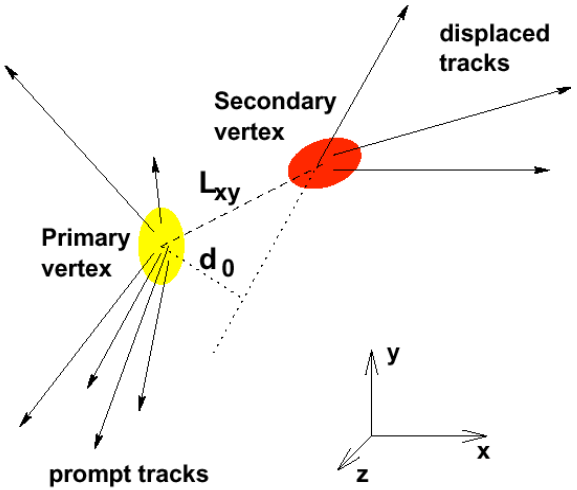



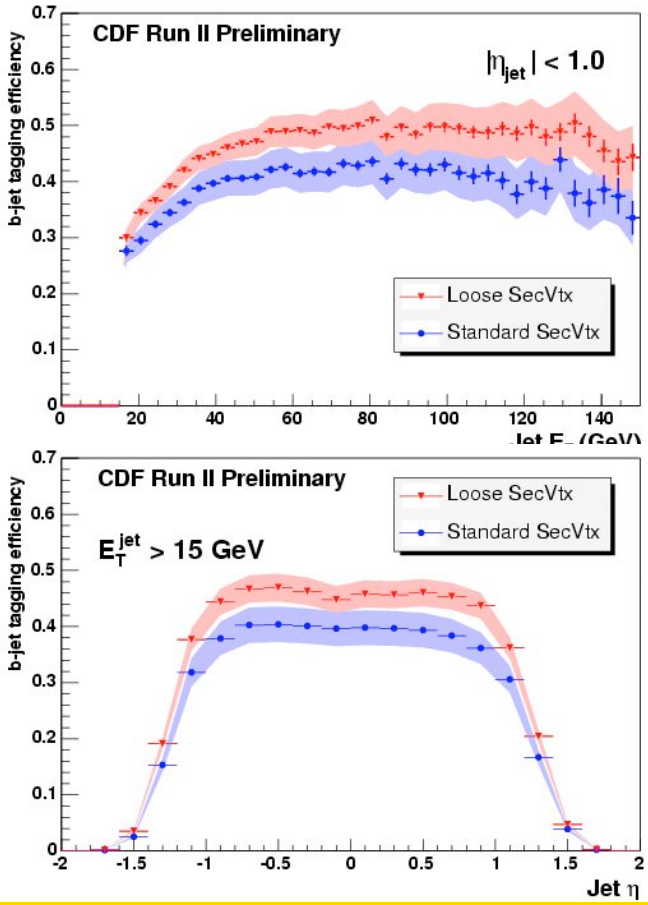
# B-jet Tagging - displaced vertices or soft leptons

Improve S:B by exploiting knowledge of B hadrons

## long-lived and massive

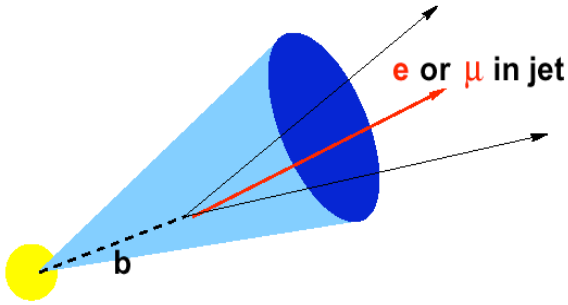
Vertex displaced tracks
Jet probability




## Semileptonic decay

Identify low-$p_T$ muon

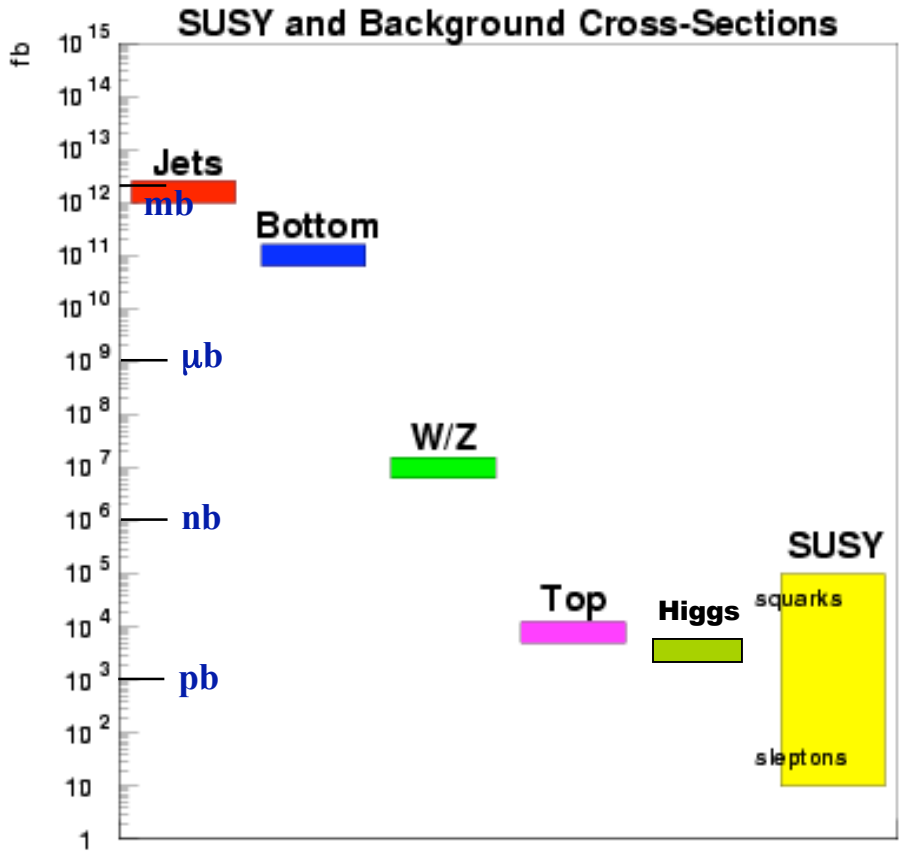



- $b \to \ell\nu c$ (BR $\sim$ 20%)
- $b \to c \to \ell\nu s$ (BR $\sim$ 20%)

| | | |
|---|---|---|
| 55% | Top Event Tag Efficiency | 15% |
| 0.5% | False Tag Rate (QCD jets) | 3.6% |

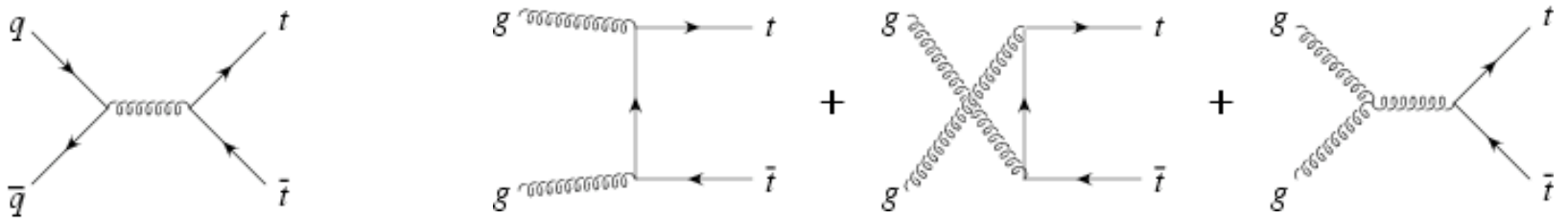
# Physics at Tevatron

- Probes physics at high $Q^2$
  - Direct searches
  - Top physics
  - High $E_T$ jets
- … to intermediate $Q^2$
  - Precision electroweak physics
- … to low $Q^2$
  - B and charm physics
- Selected topics (only a few highlights) discussed today ($L = 50 - 350\ pb^{-1}$)



# Top Quark

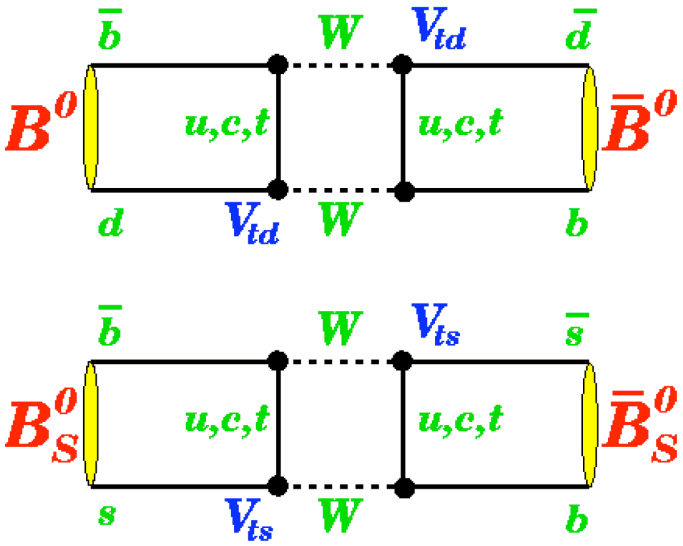
- Is it the Standard Model Top Quark?
- Does its large mass probe new physics?
- Probes:
  - Decay mode: 100% to *Wb* in SM
  - V-A coupling: W helicity in top decays
  - Event topology
  - Comparing cross sections in different decay modes and methods
  - Top mass
- Top pair production via strong interaction




85% qq 15% gg at Tevatron
0.8 event / hour at recent lum

10% qq 90% gg at LHC

# B Mixing

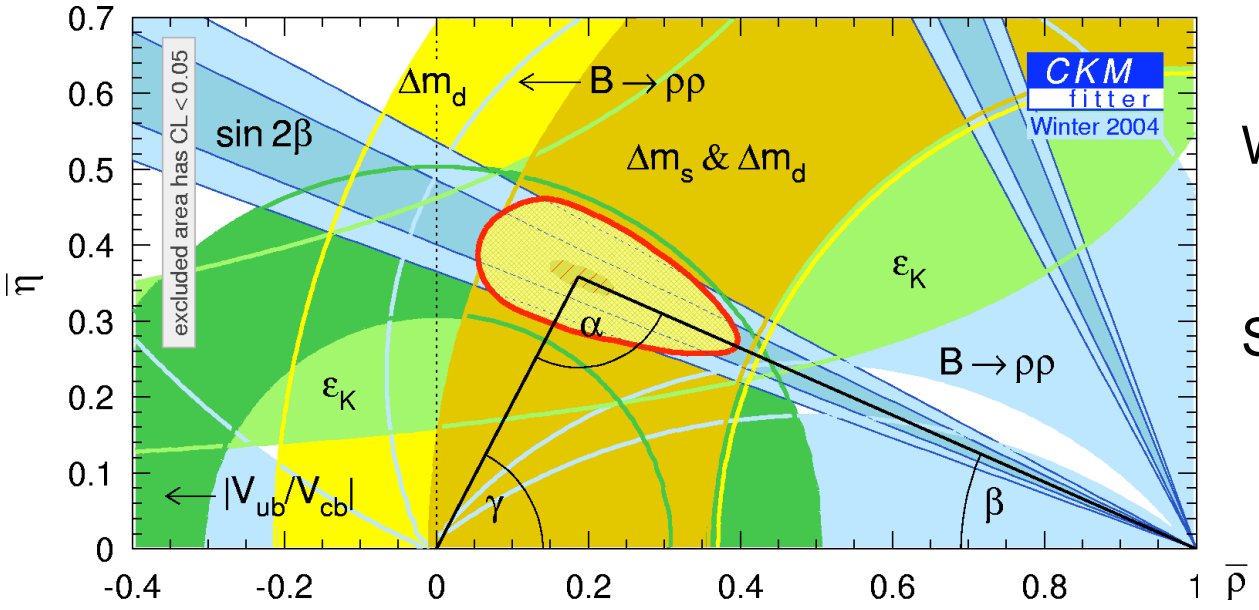



- $B_d$ , $B_s$ oscillations are sensitive to $|V_{td}|$, $|V_{td}|$
- Compromised by hadronic uncertainties
- Most cancel in $B_d/B_s$ oscillation ratio

$$\frac{|V_{td}|}{|V_{ts}|} = 1.01\xi\sqrt{\frac{\Delta m_d}{\Delta m_s}}$$

$|V_{ts}| >> |V_{td}|$ ⇨ $\Delta m_s >> \Delta m_d$

- New physics may affect $\Delta m_s/\Delta m_d$
- .$\Delta m_s$ prerequisite for time-dependent $B_s$ CP violation measurement




World limit:

$\Delta m_s > 14.4\ ps^{-1}$

SM pred. (99% prob.):

$15 < \Delta m_s < 27\ ps^{-1}$